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CARPENTRY.

VOL. I.

KINGS COLLEGE.

Details of the construction of one of the Wooden Columns in the New Hall.

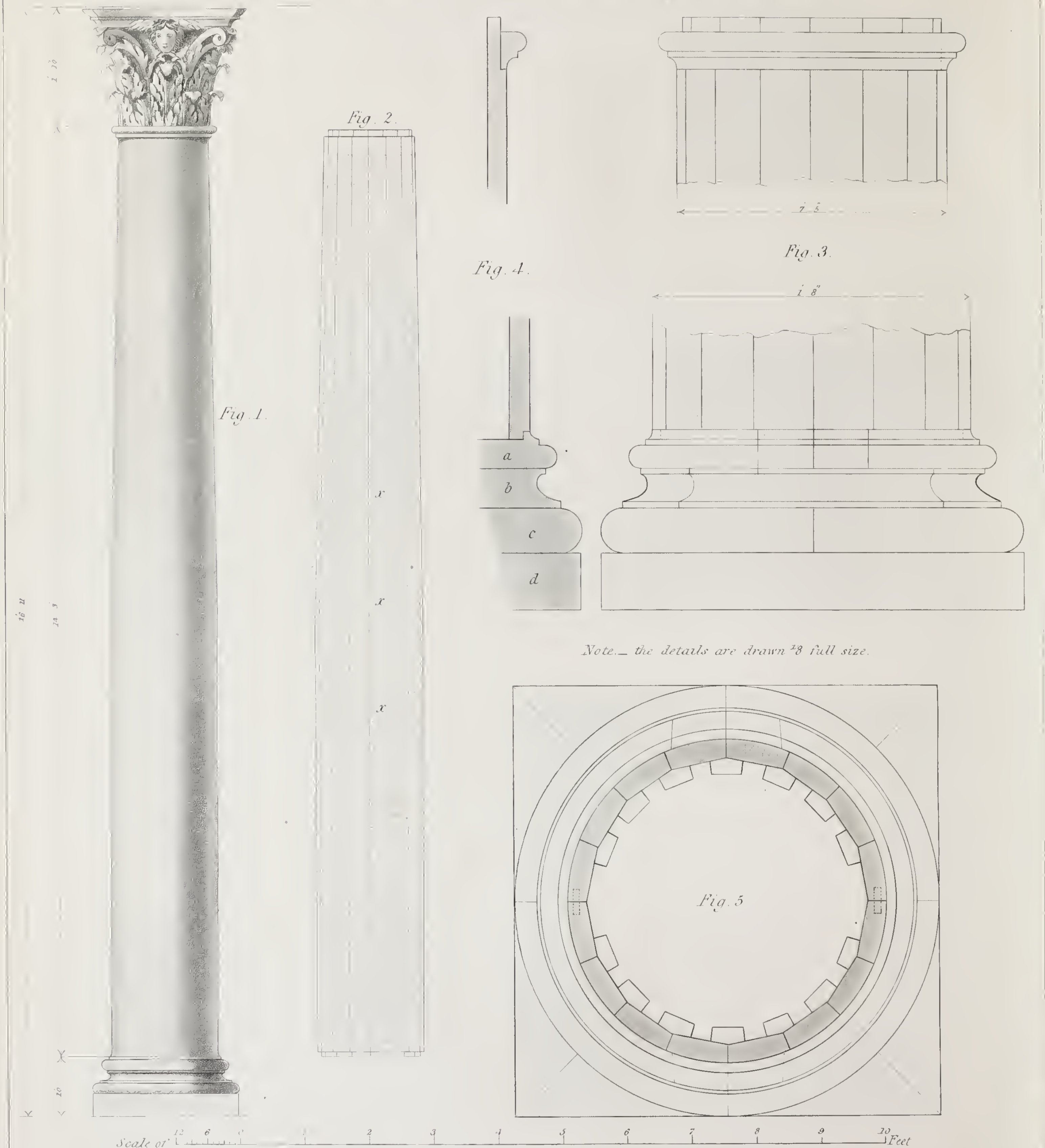


Fig 1, Elevation of Finished Column.
Fig. 2, Elevation of Shaft_The spaces x.x.x. between the dotted lines show the courses of blocking.

Fig. 3. Elevation of Shaft and Base.
Fig. 4. Section of D^o
Fig. 5. Plan of D^o

S. Smirke, del. C. Rosenberg sc.

John Weale, May 1, 1847.

CARPENTRY:

BEING A COMPREHENSIVE GUIDE BOOK

FOR

CARPENTRY AND JOINERY;

WITH

ELEMENTARY RULES FOR THE DRAWING
OF ARCHITECTURE IN PERSPECTIVE
AND BY GEOMETRICAL RULE:

ALSO,

TREATING OF ROOFS, TRUSSED GIRDERS, FLOORS,
DOMES, STAIR-CASES AND HAND-RAILS,
SHOP-FRONTS, VERANDAHS,
WINDOW-FRAMES, SHUTTERS, &c. &c.;

AND

PUBLIC AND DOMESTIC BUILDINGS,
WITH PLANS, ELEVATIONS, SECTIONS, &c. &c.

VOL I.

EIGHTY-FOUR
ENGRAVINGS.

LONDON:
JOHN WEALE,
59 HIGH HOLBORN.

1848.

LONDON:
PRINTED BY C. F. HODGSON, 1 GOUGH SQUARE, FLEET STREET.

CONTENTS OF VOL. I.

EIGHTY-FOUR PLATES.

*** The Work (Vol. II.) will be continued in Monthly Parts at 2s. 6d. each, as before, till December 1848, making 2 Vols., containing near 200 Engravings, many of the highest interest in Carpentry and Building; together with the Text explanatory of all the subjects treated of and illustrated by the Plates, and Descriptive Contents of the whole Work. The present List of Contents to be cancelled on the completion of the Work.

JOHN WEALE.

December 20th, 1847.

PREFACE

TO THE ELEMENTARY PART OF THE WORK,

BEING

Part I. or Division A.

TO a book intended merely for the use of Practical Mechanics, much preface is not necessary:—it is proper, however, to say, that whatever rules by previous authors have on examination proved to be true and well explained, these have been selected and adopted, with such alterations as a very close attention has warranted for the more easily comprehending them, for their greater accuracy or facility of application; added to these, are many examples which are entirely original, and such as will conduce very much to the accuracy of the work and to the ease of the workman.

The arrangement of the subjects in this Work, is gradual and regular, such as a student should pursue who wishes to attain a thorough knowledge of his profession: and as it is Geometry that lays down all the first principles of building, measures lines, angles, and solids, giving rules for describing the various kinds of figures used in buildings; therefore, as a necessary introduction to the art treated of, such problems of Geometry as are absolutely requisite to the well understanding and putting in practice the necessary lines for Carpentry, are now first laid down, and explained in the terms of workmen. These problems duly considered, and their results well understood, the learner may proceed to the practical part of the subject, in which Soffits claim particular attention; for, by a thorough knowledge of these, the student will be enabled

to lay down arches which shall stand exactly perpendicular over their plan, whatever form the plan may be: on this depends the well executing of all groins, arches, niches, &c., constructed in circular walls, or which stand upon irregular bases; wherefore the importance of rightly understanding these cannot be too much insisted upon, their construction being so various and intricate, and their uses so frequently required. The plates of cuneoidal or winding soffits are new, and are constructed in a more simple and more accurate manner; yet this method is only a nearer approximation to truth than the former one: the surface of a cuneoid cannot be developed; that is, it cannot be extended on a plane: it is therefore absurd to look for perfection on this subject.

The next subject which regularly presents itself is Groins; for the construction of which there will be found many methods entirely new; and besides the common figures, several are here shown which are difficult of execution, and not to be found in any other author. A variety of methods are displayed for constructing spherical niches, a form more frequently wanted than the elliptic, which only has yet been explained.

Among the various methods for finding the Lines for Roofs, an entire new one for finding the down and side bevels of purlines is given, so that they shall exactly fit against the hip rafter; and by the same method the jack rafter will be made to fit.

Of Domes and Polygons, an entirely new method is shown, for finding their covering, within the space of the board, thereby avoiding the tedious and incommodious method of finding the lines on the dome itself, as has been always practised heretofore; also a method for finding the form of the boards near the bottom, when a dome is to be covered horizontally. Of Dome-lights over staircases, or in the centre of groins, a rule upon true principles is given, for finding their proper curve against the wall, and the curve of the ribs: this has never before been made public.

Having gone thus far in the Art of Carpentry, it is necessary to say, by way of caution and guard to the ardent theorist, that there are some surfaces which cannot be developed; such as spherical or spheroidal domes, where their coverings cannot be found by any other means than by supposing the curved

surface to become polygonal ; in which case such domes may be covered upon true principles, as may be demonstrated.—Let it be supposed that a polygonal dome is inscribed in a spherical one ; then, the greater the number of sides of the polygonal dome, the nearer it will coincide with its circumscribing spherical one. Again, suppose that this polygonal dome has an infinite number of sides ; then, its surface will exactly coincide with the spherical dome ; and therefore in any thing which we shall have occasion to practise, this method will be sufficiently near; as for example, in a dome of one hundred sides, of a foot each, the rule for finding such a covering will give the practice so very near, that the variation from absolute truth could not be perceived.

Having gone through the constructive part of Carpentry, we next proceed to examples showing the best forms of floors, partitions, trusses for roofs, truss girders, domes, &c. which shall not only resist their own weight, but also any adventitious load.

In that nice and elegant branch of the Building Art called Joinery, Stairs and Hand-rails take the lead ; and notwithstanding the great importance of this subject, it has been treated by all authors without the governing principle of science. For Staircases, in general, correct methods are laid down in this Work, founded on the most obvious principles ; and which, since the first publication of the Carpenter's New Guide to the present time, it is satisfactory to say, have been put in practice, and found to answer under every circumstance and in every situation.

In this Work, a new and correct method for ascertaining the spring of the plank has been introduced instead of the former, which though very nearly was not exactly true, except when the plane of the plank was at right angles to the chord plane. The construction of rails with butt joints is likewise shewn, a method much stronger and more frequently practised than splice joints. This occasioned the introduction of additional plates.

In this Work, besides the new plates, the whole have been carefully examined, and every part of the explanation which did not appear sufficiently clear has been better expressed, and the arrangement has been improved.

To conclude; as I pretend not to infallibility, I hope to be judged with

candour, being always open to conviction, from a knowledge of the difficulty and intricacy of science; yet I hope that my labours may be of some use to others in shortening the road, and smoothing the path through which, for many years, I have been a persevering traveller for knowledge: I shall then be satisfied, and not deem my time misspent if my labours tend to the public good.

P. NICHOLSON.

Division A.

OF PRACTICAL GEOMETRY.

GEOMETRY is the science of extension and magnitude; it teaches the construction of all right-lined and curvilineal figures, and is divided into Theoretical and Practical.

The Theoretical part is founded upon self-evidence and reason; it demonstrates the construction of variously formed figures, and evinces the truth or detects the falsehood on which they are made. This is the foundation of the Practical part; and, without a knowledge of the Theory, no invention to any degree certain can be made in the Practice.

The uses of Geometry are not confined to Carpentry and Architecture, but, in the various branches of the Mathematics, it opens and discovers to us their secrets. It teaches us to contemplate truths,—to trace the chain of them, subtile and almost imperceptible as it frequently is,—and to follow them to the utmost extent.

Its uses are great and necessary in all the constructive sciences. The science of Perspective is entirely dependent upon its principles. To enumerate its many uses is beyond my power. Those who desire to become thoroughly acquainted with Geometry, will do well to study attentively the Elements of Euclid.

As my labours are not intended for the abstruse Mathematician, but for the instruction of the *Practical Carpenter*, I shall omit all speculative demonstrations, the sections of Cylinders and Globes excepted, (which are not to be found in Euclid), and confine myself to the useful part of the science, viz. Practical Geometry.

PLATE I.

DEFINITIONS.

1. A POINT has position but not magnitude.

2. A line is length without breadth or thickness.

3. A superficies has length and breadth only.

4. A solid is a figure of three dimensions, having length, breadth, and thickness.

Hence surfaces are the extremities of solids, and lines the extremities of surfaces, and points the extremities of lines.

5. Lines are either right, as A, curved, as C, or mixed of these two, as B.

6. A right or straight line lies all in the same direction between its extremities, and is the shortest distance between two points, as A.

7. A curve continually changes its directions between its extreme points, as C.

8. Lines are either parallel, oblique, perpendicular, or tangental.

9. Parallel lines are always at the same distance, and will never meet, though ever so far produced, as D and E.

10. Oblique right lines change their distance, and would meet if produced, as F.

11. One line is perpendicular to another when it inclines no more to one side than another, as G.

12. A straight line is a tangent to a curve when it is produced and touches it without cutting, as H.

13. An angle is the inclination of two lines towards one another in the same plane, meeting in a point, as I.

14. Angles are either right, acute, or obtuse, as K, L.

15. A right angle is that which is made by one straight line perpendicular to another, or when the angles on each side are equal, as G.

16. An acute angle is less than a right angle, as K.

17. An obtuse angle is greater than a right angle, as L.

18. A superficies is either plane or curved.

19. A plane, or plane surface, is that to which a right line will every way coincide ; but if not, it is curved.

20. Plane figures are bounded either by right lines or curves.

21. A solid is said to be cut by a plane when it is cut through in any particular place by that plane, and the surface through which the plane has passed is called the section of the solid.

22. Plane figures, bounded by right lines, have names according to the number of their sides, or of their angles; for they have as many sides as angles—the least number is three.

23. An equilateral triangle is that whose three sides are equal, as M.

24. An isosceles triangle has only two sides equal, as N.

25. A scalene triangle has all sides unequal, as O.

26. A right-angled triangle has one right angle, as P.

27. Other triangles are oblique angled, and are either obtuse or acute.

28. An acute-angled triangle has all its angles acute, as M or N.

29. An obtuse-angled triangle has one obtuse angle, as O.

30. A figure of four sides and angles is called a quadrangle, or quadrilateral, as Q, R, S, T, U, and V.

31. A parallelogram is a quadrilateral, which has both pairs of its opposite sides parallel, as Q, R, U, and V; and takes the following particular names.

32. A rectangle is a parallelogram having all its angles right angles, as Q and R.

33. A square is an equilateral rectangle, having all its sides equal, and all its angles right angles, as Q.

34. A rhombus is an equilateral parallelogram, whose angles are oblique, as U.

35. A rhomboid is an oblique-angled parallelogram, as V.

36. A trapezium is a quadrilateral which has neither pair of its sides parallel, as T.

37. A trapezoid has only one pair of its opposite sides parallel, as S.

38. Plane figures, having more than four sides, are in general called polygons, and receive other particular names according to the number of their sides or angles.

39. A pentagon is a polygon of five sides, a hexagon has six sides, a heptagon seven, an octagon eight, a nonagon nine, a decagon ten, an undecagon eleven, and a dodecagon twelve sides.

40. A regular polygon has all its sides and its interior angles equal; and if they are not equal, the polygon is irregular.

41. An equilateral triangle is also a regular figure of three sides, and a square is one of four; the former being called a trigon, and the latter a tetragon.

42. A circle is a plane figure bounded by a line called the circumference, which is every where equidistant from a certain point within, called its centre.

43. The radius of a circle is a right line drawn from the centre to the circumference, as *a b* at W.

44. A diameter of a circle is a right line drawn through the centre, terminating on both sides of the circumference, as *c d* at W.

45. An arch of a circle is any part of the circumference.

46. A chord is a right line joining the extremities of an arch, as *a b* at X.

47. A segment is any part of a circle bounded by an arch and its chord, as X.

48. A semicircle is half the circle, or a segment cut off by the diameter, as Y.

49. A sector is any part of a circle bounded by an arch and two radii, drawn to its extremities, as Z.

50. A quadrant, or quarter of a circle, is a sector having a quarter of the circumference for its arch, and the two radii are perpendicular to each other, as A 1.

51. The height or altitude of any figure, is a perpendicular let fall from an angle, or its vertex, to the opposite side, called the base, as *a b* at B 2.

52. When an angle is denoted by three letters, the middle one is the place of the angle, and the other two denote the sides containing that angle; thus, let *a b c* be the angle at C 3, *b* is the angular point, and *a b* and *b c* are the two sides containing that angle.

53. The measure of any right-lined angle is an arch of any circle contained between the two lines which form the angle, the angular point being in the centre, as D 4.

PLATE II.

PROBLEMS.

Figure 1.—*To draw a Perpendicular to a given Point in a Line.*

A B is a line, and *c* a given point; take *a* and *b*, two equal distances on each side of *c*, and with the foot of the compasses in *a* and *b* make an intersection *d*, and draw *d c*, which is the perpendicular.

Fig. 2.—*To make a Perpendicular with a Ten Foot Rod.*

Let *a b* be six feet, then take eight feet, and from *b* make an arch at *c*, and from the point *a* with the distance of ten feet make a cross at *c*, then draw *c b*, which is the perpendicular.

Fig. 3.—*To let fall a Perpendicular from a given Point to a Line.*

From the given point *c* make an arch to cross the line in *a* and *b*, and from *a* and *b* make an intersection at *d*, and draw *c d* the perpendicular.

Fig. 4.—*To draw a Perpendicular upon the End of a Line.*

Take any point *d* at pleasure above the line, and with the distance *d b* make an arch *a b c*, and draw a line *a d* which produce to cut it at *c*, and draw *c b* which is the perpendicular.

Fig. 5.—*To divide a Line in two equal Parts by a Perpendicular.*

From the extreme points *a* and *b* describe two arches to intersect at *c* and *d*, and draw *c d*, which divides the line *a b* in two equal parts.

Fig. 6.—*To divide any given Angle into two equal Angles.*

Take two equal distances *a b* and *a c* on each side of the angular point *a*, and with the same opening of the compass or any other of sufficient extent, place the foot in *b* and *c*, make an intersection at *d*, and draw *d a*, which will divide the angle into two equal parts.

Figs. 7, 8.—*An Angle being given, to make another equal to it, from a given Point in a right Line.*

Let *b a c* be the angle given, and *c d* a right line, *c* the given point; on *a* make an arch *b c* with any radius, and on *c* with the same radius describe an arch *d e*, take the chord of *b c*, set it from *d* to *e*, and draw *e c*, then the angle *e c d* will be equal to *c a b*.

PLATE III.

Fig. 1.—*Upon a Right Line to make an equilateral Triangle.*

Take *a b* the given side, and from *a* and *b* make an intersection at *c*, and draw *c a* and *c b*.

Fig. 2.—*Upon a right Line to make a Square.*

With the given side *a b*, and from the points *a* and *b*, describe two arches to intersect at *e*, divide *b e* into two equal parts at *f*, make *e d* and *e c* each equal to *e f*, draw *a d*, *d c*, and *c b*.

Figs. 3, 4, 5, 6.—*The Side of any Polygon being given, to describe the Polygon to any Number of Sides whatever.*

On one extreme of the given side make a semicircle of any radius, but it

will be most convenient to make it equal to the side of the polygon; then divide the semicircle into the same number of equal parts as you would have sides in the polygon, and draw lines from the centre through the divisions in the semicircle, always omitting the two last, and run the given side round each way upon these lines, join each side, and it will be completed.

Example in a Pentagon. FIG. 4.

Let *a b* be the given side, and continue it out to *c*; on *a*, as the centre with the radius *a b*, describe a semicircle, divide it into five equal parts; through 2, 3, 4, draw *a* 2, *a d*, *a e;* make *b e* equal to *a b*, 2 *d* equal to 2 *a* or *a b;* join 2 *d*, *d e*, and *e b*. In the same manner may any other polygon be described.

N.B. This depends upon the equality of the angles upon equal arcs. See Fig. 3.

FIG. 7.—*Through a given Point* a *to draw a Tangent to a given Circle.*

Draw *a o* to the centre, then through *a* draw *b c* perpendicular to *a o*, it will be the tangent.

FIG. 8. *A tangent Line being given, to find the Point where it touches the Circle.*

From any point *a* in the tangent line *b a*, draw a line to the centre *o*, and divide *a o* into two equal parts at *m*, and with a radius *m a*, or *m o*, describe an arch, cutting the given circle in *n*, which is the point required.

FIG. 9.—*Two right Lines being given, to find a mean Proportion.*

Join *a b* and *b c* in one straight line, divide *a c* into two equal parts at the point *o*, with the radius *o a* or *o c* describe a semicircle, and erect the perpendicular *b d*, then is *a b*, to *b d*, as *b d*, is to *b c*.

FIG. 10.—*Through any three Points to describe the Circumference of a Circle.*

From the middle point *b* draw the chords *b a* and *b c* to the two other points *a* and *c*, divide the chords *a b* and *b c* into two equal parts by perpendiculars meeting at *o*, which will be the centre.

FIG. 11.—*To find the length of any Arc* A B C *of a Circle.*

Draw the chord *A C* and produce it towards *E;* bisect the arc *A B C* in *B*, and make *A D* equal to twice *A B;* divide *C D* into three equal parts, and set one out to *E;* then *A E* is the length of the arc.

PLATE IV.

FIG. 1.—*Three straight Lines being given, to form a Triangle.*

Take one of the given lines *a b*, and make it the base of the triangle; take the other line *a c*, and from *a* describe an arch at *c;* then take the third line *b c*, and from *b* describe another arch crossing the former at *c*, and join *a c* and *b c*.

Note. That any two lines must be greater than a third.

FIGS. 2, 3.—*To make a Quadrangle equal to a given Quadrangle.*

Divide the given quadrangle, *fig.* 2, in two triangles; make the triangle *e f g* equal to *a b c*, and *e g h* equal to *a c d*, and it is done.

FIGS. 4, 5.—*Any irregular Polygon being given, to make another of the same Dimensions.*

Divide the given polygon, *fig.* 4, into triangles, and in *fig.* 5 make triangles in the same position, respectively equal to those in *fig.* 4; then will the irregular polygon *f g h i k* be equal and similar to *a b c d e*.

FIG. 6.—*To make a Rectangle equal to a given Triangle.*

Draw a perpendicular *c d*, divide it into two equal parts at *e*, through *e* draw *f g*, parallel to the base *a b*; draw *a f*, *b g*, perpendicular; then will the rectangle *a b g f* be equal to the triangle *a b c*.

FIG. 7.—*To make a Square equal to a given Rectangle.*

Let *a b c d* be the given rectangle; continue one of its sides as *a b* out to *e*, make *b e* equal to the other side *b c*, divide *a e* in two equal parts at *i*, with the radius *i e* or *i a* make a semicircle *a f e*, and draw *b f* perpendicular to *a b;* make the square *b f g h*, which is equal to the parallelogram *a b c d*.

FIG. 8.—*To make a Square equal to two given Squares.*

Make the perpendicular sides *a c* and *a b* of the right-angled triangle *c a b* equal to the sides of the given squares *A* and *B*, draw the hypothenuse *c b*, which is the side of the square *C*, equal to the two squares *A* and *B*.

FIG. 9.—*To make a Square equal to three given Squares.*

Let *A*, *B*, *C* be the three squares; make *a b* equal to the side of *B*, *a c* equal

to the side of *A*, at right angles to *a b*; join *b c*, then make *a d* equal to *b c*, make *a e* equal to the side of *C*, join *d e*, which will be the side of the square *D* equal to the squares *A*, *B*, *C*.

PLATE V.

Fig. 1.—*To draw a Segment of a Circle to any length and height.*

a b is the length, *i h* the height; divide the length *a b* into two parts by a perpendicular *g c:* divide *a h* by the same method, then their meeting at *g* will be the centre; fix the foot of the compasses in *g*, extend the other leg to *h*, make the arch *a h b*, which is the segment.

Fig. 2.—*To draw a Segment by Rods to any Length and Height.*

Make two rods *c e* and *c f* to form an angle *e c f*, so that each may be equal to *a b*, the opening; place the angle *c* to the height, and the edges to *a* and *b*, put a piece *a b* across them to keep them tight, then move your lath round the points *a*, *b*, and the point *c* will describe the segment required.

Fig. 3.—*To describe a Segment of a Circle at twice, upon true Principles, by a flat Triangle.*

Let the extent of the segment be *a b*, its height *c d*, from the extreme *b* to the top *d* draw *b d*, through the point *d* draw *e d* parallel to the base *a b*, equal in length to *d b*, stick a nail or pin in *a*, and another in *d*, describe one half, as you see at *G*; then move the nail, or pin, out of *a*, stick it in the point *b*, and describe the other half.

Fig. 4.—*The transverse Axis* a b *and conjugate* g c *of an Ellipsis being given, to draw its Representation.*

Draw *a d* parallel and equal to *n c*, bisect it in *e;* draw *e c* and *d g* cutting each other at *m*, join *m c*, bisect it by a perpendicular meeting *c g*, produced at *h;* draw *h d*, cutting *b a* at *k*, and make *n i* equal to *n k; n l* equal to *n h;* through the points *i*, *l*, *k*, *h*, draw the lines, *h i*, *k l*, and *i l*, *h k*, then describe the four sectors by help of the centres, *i*, *l*, *k*, *h*, and it will be the representation required.

Fig. 5.—*To describe an Ellipsis by Ordinates.*

Make a semicircle on the length *a b*, divide it into any number of equal parts, as 16, on the end at *a* make *a* 8 perpendicular, equal to half the width, and draw

the ordinates through all the points in the semicircle, draw the line 8 1 to the centre, then *a* 1 8 will be a scale to set off the ordinates; take 1 1 from the scale, and set it from 1 to 1 in your oval both ways at each end; then take 1 2 in your scale, and set it to 1 2 in the oval, and find all the other points in the same manner; a curve being traced through these points will be the true ellipsis.

PLATE VI.

FIG. 1.—*To make an Ellipsis with a String.*

Take the half *a g* of the longest diameter *a b*, and with that distance fix the foot of the compass in *c*, cross *a b* at *e f*, in which stick two nails or pins, then lay a string round *e f c*, fix a pencil at *c*, and move your hand round, keeping the string tight, the pencil will describe the ellipsis.

FIG. 2.—*To describe an Ellipsis by a Trammel.*

1 2 3 is a trammel rod: at 1 is a nut with a hole to hold a pencil; at 2 and 3 are two other sliding nuts; make the distance of 2 from 1, half the shortest diameter of the ellipsis, and from the nut 1 to 3 equal to half the longest, the points 2 and 3 being put into the grooves of the same size, move your pencil round at 1, and it will describe the true curve of an ellipsis.

FIG. 3.—*An Ellipsis being given, to find the Centre and two Axes.*

Draw any two parallel lines *a b* and *c d* at pleasure, divide each of them in two equal parts at the points *e* and *f*, and through *e f* draw the line *k l*, divide *k l* into two equal parts at the point *g*, place the foot of the compass in *g*, with the other foot make two crosses *h* and *i*, on the circumference; draw a line *h i*, through *g* draw *m n* parallel to *h i*, also through *g* draw *o p* at right angles to *m n*; then *o p* is the transverse axis, and *m n* the conjugate, and *g* the centre of an ellipsis.

FIG. 4.—*To proportionate one Ellipsis within another; that is, to give it the same Length in proportion to its Width, that the Length of the other has to its Width.*

Let the given ellipsis be *a d b c*, make the parallelogram *e h f g* to touch the sides and ends of the ellipsis, draw the diagonals *e f* and *g h* of the rectangle, let *r q* be the width of the lesser ellipsis given, through the point *q* or *r* draw *l o* or *m n*, parallel to the transverse axis at the points *m* and *n* where it cuts the diagonal, draw *m l* and *n o* parallel to the conjugate axis, will also show its length.

Fig. 5.—*To describe an Ellipsis about a Parallelogram, to have the same Length in Proportion to its Width, that the Length of the Parallelogram has to its Width.*

Let the given parallelogram be *a b c d;* let the diagonals *a c* and *b d* be drawn from the centre *i;* draw the quarter of a circle, 2 1 *k*, to half the width of the rectangle; divide the quadrant into two equal parts at 1; through the point 1, draw the line *l* 3 parallel to the transverse axis, to cut the diagonal *b d* in the point 3; then draw the lines 3 2 and 3 4: again, draw *f d* parallel to 2 3, then *i f* will be half the width; and *d e* parallel to 3 4, and *i e* will be half the length of the ellipsis: make *i h* equal to *i e*, and *i g* equal to *i f*, which will give the four points through which the ellipsis must pass; describe the curve, and the thing will be done.

Fig. 6.—*To divide a Line in the same Proportion as another is divided.*

d a is a line given already divided, and *d e* is a line to be divided in the same proportion. Make any angle at *d;* join *a e*, draw *b f* and *c g* parallel to *a e*; then *d e* is divided at *f* and *g* in the ratio as *a d* at *b* and *c*.

Fig. 7.—*To do the same by an equilateral Triangle.*

a b is the given line divided: from *c* take two equal distances *c d*, *c d*, and by drawing lines from the several points in *a b* to *c* cutting *d d*, *d d* will be divided as *a b*.

Fig. 8.—*To make an Octagon the nearest Way from a Square.*

Draw the diagonals of the square to cross at *e*, fix the foot of your compass in *c*, and take the distance *c e* and make an arch *f e g;* then set your gauge to *d f* or *b g*, which will gauge off each angle.

PLATE VII.

CONIC SECTIONS BY INTERSECTING LINES.

DEFINITIONS.

1. A cone is a solid having a circular base, from which the sides continually diminish in straight lines to a point in which they all terminate, and this point is called the vertex.
2. Opposite cone is another cone joining the vertex of the other cone, with its sides every where in the same straight line passing through the vertex as a common point.
3. A right line joining the vertex and the centre of the basis is called the axis.

4. If a cone be cut by a plane passing entirely through its curved surface, but not parallel to the base nor to the axis, nor to a plane touching the side of the cone, the section is an ellipse, excepting in one position which is a circle.
5. If a cone be cut by a plane parallel to its sides, the section is a parabola.
6. If the cone be cut by a plane passing through the opposite cone, the figure will be an hyperbola.

To describe the Ellipsis from the Cone.

FIGURE *A*.—Let *B* be half the circle of the base of the cone, *n* the vertex at the top; then *n a* and *n d* are two sides; let the cone be cut by a plane passing through *g h;* bisect *g h* at the point *k*, and through *k* draw *r q*, parallel to the base *a d;* also bisect *r q* in *m*, describe the semicircle *r p q*, draw *k p* at right angles to *q r;* and *g h* is the length of the ellipsis, and *h k* half its width; from which the figure may be described at *C*, as explained in the next plate.

To describe the Parabola from the Cone.

FIGURE *A*.—Let *i e* be the axis of the parabola, parallel to the other side *n d* of the cone, and through *e* draw *e c* at right angles to the base; then will *e c* be half the width of the parabola, and *e i* its height; then the *figure* will be described, as at *D*, by intersecting lines upon each ordinate, up to the crown, from the equal divisions on each side.

To describe the Hyperbola from the Cone.

FIGURE *A*.—Let the axis of the hyperbola be *i f*, cut by a plane passing through *f* and *i*, till it cut the opposite cone at *l;* draw *f b* at right angles to *a d*, then is *f i* the height of an hyperbola, and *f b* half the width of the base, and *i l* its transverse axis; then make *f i* at *E* equal to *f i* in *figure A*, make *i l* in *E* equal to *i l* in *figure A*, *b b* in *E* equal to twice *f b* in *figure A;* let the base *b b* in *E* be divided into ten equal parts, as at 0, 1, 2, 3, 4, 5, *that is*, into five equal parts on each side from the centre, and draw lines to the point *l* through these points; likewise divide the height into five each way, and draw lines to the vertex at *i;* this will show the points through which the curve must pass.

PLATE VIII.

To draw any Semi-ellipsis upon the transverse or conjugate Axis, or even a Semicircle itself, by a new Method of intersecting Lines.

FIGURES *A* and *B*.—Let the given axis be *a b*, and let it be divided into any

number of parts, as 10; also let the height be divided into half the number of parts; make *e d* equal *e c*, that is, to the height of the arch; then, from the point *d* draw lines through the equal divisions of the axis *a b;* likewise, through the points 1, 2, 3, 4, 5, in the height *a f*, draw lines tending to the vertex at *c*, which will intersect at the points *h, i, k, l;* and lines being drawn through the divisions of *b g* to *c*, at the crown, in the same manner, will give the points *n, o, p, q;* a curve being traced through these points, will form the true curve of an ellipsis.

The semicircle, *figure C*, is drawn in the same manner, by making *a f* equal to one half of *a b*.

To draw the true Segment of a Circle, by the Method of intersecting Lines.

FIGURE *D*.—Let *a b* be the length of the segment, and *o c* its height, and draw the chord *b c* for one half of the segment, and draw *b m* at right angles to *b c;* and from the point *o* divide *a b* each way, into five equal parts; also from *c*, divide *c m*, and *c n*, each into five equal parts; and draw 1 1, 2 2, 3 3, 4 4, 5 5, on each side, through the divisions 1, 2, 3, 4, 5 on *a s*, and 1, 2, 3, 4, 5 on *b r;* draw lines to *c*, which will intersect the other lines at the points *d, e, f, g*, and *h, i, k, l:* the curve being traced, the thing is done.

To draw a flat Segment of a Circle nearly true.

FIGURE *E*.—Divide the length of the segment into equal parts each way, from the centre *d*, as before, and draw the lines 1 1, 2 2, 3 3, 4 4, 5 5, all at right angles, to the length *a b*; lines being drawn to the crown at *c*, from the divisions at each end, will show the points which the segment must pass through; the curve being traced, the thing is done.

Remark.—Although this last method is not the true segment of a circle, but a parabolic curve, yet it will be found useful in practice, in tracing any segment whose height is not more than one tenth part of its length: if the centre of the segment is found, and drawn with a compass, the difference will hardly be visible, and the flatter the segment, this difference will become the more imperceptible; but if the height exceeds one tenth of its length, the difference will be visible; for then the arch will be quicker at the vertex, and get flatter and flatter towards each extreme.

In the same manner may all kinds of rampant ellipses be described, or any segment of them, as at *F* and *G*, also a rampant parabola in the same manner as at *H*.

PLATE IX.

THE SECTIONS OF A CYLINDER.

DEFINITIONS.

A cylinder is a figure generated by the revolution of a right-angled parallelogram about one of its sides; consequently the ends of the cylinder are equal circles, and the line passing through the centre of the cylinder, is called the axis.

The section of a cylinder, cut by any plane, is an ellipsis, or circle, or rectangle, proved by the writers on Conic Sections.

To find the Section of a Semi-cylinder, by Ordinates, when it is cut at right Angles to the Plane, passing through its Axis, in the Direction a b. FIG. 1.

Let the circle of the base be divided into equal parts at *A*, and drawn parallel to the axis of the cylinder, or to the line *a b*, at the points 0, 1, 2, 3, 4, 5, &c. and from these points draw lines at right angles to *a b;* then *B* being pricked from *A*, as the figures direct, *B* will be the section of the cylinder.

DEMONSTRATION.

Conceive the semicircle *A* at the base to be turned at right angles to the plane, also the semi-ellipsis *B* at right angles to the same plane; then will the ordinates of *B* be parallel and perpendicular over the ordinates of *A*, and every corresponding point in the circumference of *B* will fall perpendicular to the same corresponding points in *A:* therefore *B* is the true section of the cylinder, cut in this position.

To cut a Cylinder in the direction V, W, *upon a Plane, passing through its Axis, to make an acute Angle with that Plane.* FIG. 2.

Let *C*, at No. 1, be the given angle, which the section at *B* is to make with the plane of the cylinder; take *a b* in *figure* 2, that is, the radius of the base, and set it from *b c*, at No. 1, perpendicular to *i b;* draw *c c* parallel to *i b*, also from *c* draw *c e* perpendicular to *i b;* then take the distance *c i*, set it from *i* to *f*, in *figure* 2, at *B;* likewise take *i e* from No. 1, and set it from *i* to *e* in *figure* 2, at *B;* draw *e d* parallel to *m n*, to cut the rake in *d*, and join *d f;* then is *d f* the bevel of the first ordinate of the section *B*. And draw the lines *e c* and *d a* parallel to the axis; join *a c* at *A;* then will *a c* be the bevel of the first ordinate of the base. Draw all the other ordinates of *A* parallel to *a c*, and at the points 1, 2, 3, 4, &c. in *m n*, draw lines parallel to the axis of the cylinder, to cut the

raking line *V W* at 1, 2, 3, 4, &c. From these points let lines be drawn parallel to *d f;* then the ordinates of *B*, being pricked from the same corresponding ordinates of the base at *A*, will give the section of the cylinder.

Note.—The point *f* will fall beyond the sweep at the section *B*.

DEMONSTRATION.

Let the plane *B* be conceived to be turned round the line *V W* to make an angle at the point *i*, with the plane *n m V W* equal to the angle *e i c*, No. 1; and conceive a straight line drawn from *e* perpendicular to the plane *n m V W*, the line thus supposed to be drawn will be parallel to the plane *A* of the base, and the triangle formed by *i f*, *i c*, and the perpendicular from *e*, will be equal and similar to the triangle *c i e*, No. 1: then because *d e* and the perpendicular are both parallel to the base, the line that joins the points *e* and *f* will also be parallel to the base; and because *e d* is equal to *a* 6, the triangle *e d f* will be equal and similar to the triangle 6 *a c* in the plane of the base *A*: and because 6 *c* and the perpendicular drawn from *e* are both in a plane parallel to the axis, the plane passing through *d f* and *a c* will also be parallel to the axis: but *d f* is also in the plane of the section, for the point *d* is in the intersection of *V W*, and the point *f* will be in the perpendicular drawn from *e*, therefore if a series of planes be conceived to be drawn through the ordinates of the base parallel to the plane passing through *a c* and *d f*, the intersection of these planes on the plane of section *B* will be parallel to the ordinates of *B*, and every two corresponding lines will be in a plane parallel to the axis, and therefore as the lines formed by the intersections of the series of planes in the section *B*, are equal to those in the base *A*, the extremities are in the section of the cylinder.

To cut a Segment of a Cylinder, in the Direction a b, *to make an obtuse Angle with the Plane of the Segment.* FIG. 3.

Let No. 1 be the angle given, which the section *B* is to make with the plane of the segment; from *f* in No. 1, draw *f g* at right angles to *f c*, and *g e* also perpendicular, to make the right-angled triangle *e g f*. And in *figure* 3, at *B*, draw *g f*, at right angles to *a b*, and make *g e* equal to *g e* at No. 1. Also, make *g f* at *B* equal to *g f* at No. 1. Draw *e d* at *B*, parallel to *M N*, and at the point *d*, where it intersects the line *a b*, join *d f;* then *d f* is one of the ordinates. From *e* and *d*, draw the two parallel lines *e c* and *d* 3, join *c* 3; then *c* 3 will also be an ordinate of the base. Draw parallel lines at discretion to *c* 3, for the other ordinates of the base; and from their intersection upon *m n* draw lines parallel upon the cylinder, to cut *a b* in 1, 2, 3, 4, &c. and from these points draw parallel lines to *d f*, which are the ordinates of *B;* these, being pricked from the base as the figures direct, will give the points through which the curve must pass, which being traced, will be the true section of the segment of the cylinder.

DEMONSTRATION.

Is the same as the preceding demonstration.

That the reader may perceive this more clearly, the best way is to draw those lines on pasteboard, the section and the end being made to turn round, in their proper position, then the demonstration will be clearly seen.

Figure 4 is to be laid down and demonstrated in the same manner as Figure 2.

Remark.—Upon these figures depend the whole principles of hand-rails for stairs. The reader ought to understand how to form the section of a cylinder, in any case whatever; for the face or raking mould of a hand-rail is nothing but the double section of a cylinder, as in *figure* 4, at *B*, where the double circle upon the base *A* represents the plan of a rail, and the bevel at No. 1, *figure* 4, represents the spring of the plank, and *a b* the pitch of the rail: therefore, it is very necessary that the reader should have a knowledge of these figures and their demonstrations; and not be satisfied with only doing it, but read these demonstrations, and consider them with attention; then he will be able to see the reason why every line is drawn in the manner it is.

PLATE X.

THE SECTIONS OF A GLOBE, OR ANY OTHER FIGURE STANDING UPON A CIRCULAR BASE; ALSO, THE SECTION OF ANY FIGURE STANDING ON AN IRREGULAR BASE.

Definition.—A globe is a figure generated by the revolution of a semicircle round its diameter, which becomes the axis of the globe.

AXIOMS; OR, SELF-EVIDENT TRUTHS.

1*st.* From this definition it appears, that every two sections passing through the centre, are equal to each other.

2*nd.* Every section of a globe, cut by a plane, is a circle; for the generating circle may be made to revolve round any line, as an axis; and therefore every point in it will generate a circle, whose diameter must be twice the radius of that circle, distant from the axis of the globe.

3*rd.* If a semi-globe is cut by a plane at right angles to the plane of its base, the section will be a semicircle.

To find the Section of a Semi-globe cut by a Plane at right Angles to the Plane of its Base. Fig. 1.

It appears from the last axiom, that there is no tracing required: for, let the section be cut across *a b*, *figure* 1; divide *a b* in two equal parts at the point *c*;

and on *c*, as a centre with the radius *c a* or *c b*, describe the semicircle *A*, which is the true section required.

The same by Ordinates. FIGS. 1 and 2.

Draw any line *d e* through its centre, and let *a b* be the place of the section upon the base, as before; place the foot of your compass in the centre of the globe at *f*, and, with a radius *f c*, draw an arch from *c* to *g*, in the diameter *d e;* the foot of your compass remaining still in *f*, draw the concentric dotted circles from *c b* to *f e*, and at the intersecting points 1, 2, 3, 4, 5, in *f e*, and likewise in *c b*, erect perpendiculars to those lines; then *A* being pricked from *C*, as the figures direct, will give the points through which this semicircle must pass.

DEMONSTRATION.

Conceive the semicircle *C* to stand at right angles upon *d e*, also the section *A* to be at right angles to *a b;* now it is evident, if *g* 1 is the height of the globe over the point *g* in the base, *c* 1, which is equal to *g* 1, must also be the height of the section, because the points *c* and *g* stand at an equal distance from the centre; and therefore the point 1 over *c*, is in the surface of the globe. In the same manner it may be proved, that any other points carried round by the dotted lines are in the same surface: but the section that stands upon *a b*, in *A*, is a semicircle; and consequently the method of tracing is also a semicircle.

Observation.—Hence appears the erroneous principle of tracing used by a late writer on this subject, as you may see at *figure* 2, where *A* is the section of a globe, and the bracket at *D* is the section across the diameter. *A* is truly traced from *D*, because the ordinates are carried round in circles; but by his method of tracing, as you see at *C*, upon the other side, the point of the bracket *C* falls within the sweep of the circle, by reason of the ordinates of *C* being carried straight through between the two bases, which I have proved to be false. And this he has applied in bracketing up the angles in the square well-hole of a staircase, to the circular curb of a sky-light, which, if truly done, is nothing else but upon the same principle as the sections of a globe.

FIGURE 3 is done upon the same principle as *figure* 1. *A* is the section traced from *C*, and wants no other demonstration than what has been given in *figure* 1.

FIGURE 4 is an ogee section, standing upon a circular base across the diameter; and *A* is the section traced from it, upon the same principles as *figure* 1.

From these examples it is clear that this method of tracing does not depend on the form of the top, but entirely upon the base. These figures are supposed to be generated round an axis; and, as every circle is carried round at an equal distance from the axis, the perpendicular height of the figure, upon any circle,

must be the same height in every point throughout the circle; which proves itself to be the only method for any thing of this kind.

A Semi-globe being cut by a cylindrical Surface perpendicular to the Plane of its Base, to find the Form of a Veneer that will bend round it.—FIG. 5.

Let *d e* be drawn through the centre *f;* and place the foot of your compass in *f*, the centre; and draw the points *b*, 1, 2, 3, 4, 5, which are equally divided from the centre at *b* in the circular surface, draw the concentric dotted lines round to the diameter *d e*, at 0, 1, 2, 3, 4, and at these points raise the perpendiculars 0 0, 1 1, 2 2, 3 3, 4 4. Take the stretch-out round *b* 1 2 3 4 5, which is one-half; and lay it upon the base of No. 1 each way, from 0, 1, 2, 3, 4, &c., and No. 1 being pricked from *A*, *figure* 5, as the figures direct, will give the points through which the curve must pass for the veneer.

DEMONSTRATION.

For, since the section standing upon *d e* is a semicircle, which is equal to the semicircle upon the base; and as the points 1, 2, 3, 4, in the circular surface, stand at the same distance from the centre *f*, as 0, 1, 2, 3, 4, in *d e;* now if the point *o* at No. 1 is made to coincide with the point *b* in *figure* 5, then the height *o o*, standing over the point *b*, will be equal to the height *o o* at *A;* but these points are at an equal distance from the centre, therefore the top of each ordinate will be in the surface of the globe. In the same manner every other point may be proved, when bent round and elevated, to be of the same height, and at an equal distance from the centre with those of *A;* and therefore No. 1 is the true form of the veneer.

To find the Ribs of a Gothic Niche, FIG. 6. *being the Plan, and No.* 1. *the Front Elevation.*

Take the length of each base upon the plan, and make them the bases of No. 2, No. 3, No. 4, and No. 5, respectively; divide each base into six equal parts; also divide the half of No. 1. into six parts, and draw the ordinates from the equal divisions, perpendicular to each base; then prick each from No. 1, as the figures direct, which will give the form of each rib. This wants no demonstration.

OF CARPENTRY.

LININGS FOR SOFFITS.

DEFINITION.

The lining of a Soffit, in the Theory of Carpentry, signifies the covering of any concave surface of a solid spread out on a plane.

Soffit, in Architecture, is the under side of the head of a door, window, or the intrados of an arch, and may be either plane or curved.

PLATE XI.

To stretch out a Soffit, when a Window or Door, having a semicircular Head, cuts into a straight Wall in an oblique direction.

LET *C* be the plan, or opening, of the window in *fig. A*, and let the base of the semicircle *B* be drawn at right angles to the jambs, or sides, of the plan *C*; divide the semicircle into any number of equal parts, as ten, and draw the ordinates across the plan; extend the parts round *B* upon the stretch-out line, the ordinates being drawn from the divisions across, and traced off from the plan *C*, as indicated by the figures and letters; the lining of the soffit will then be completed.

If a cylinder is made to the thickness of the wall, the end of it may be traced from the semicircle *B*.

To draw the Lining of a Soffit when the Top is a Semicircle, cutting right into a circular Wall.

FIG. *E*. This and the other below are performed the same as that above, with this difference, that the circular plan must be the regulating line, instead of the straight plan.

Fig. *I.* shows the method when a circular-headed window cuts obliquely into a circular wall.

Note.—In all kinds of cylindro-cylindric soffits, when the two jambs are parallel, the straight line, from which the ordinates of the soffit are measured, must be drawn at right angles to the jambs, as is shown in this plate: for the want of this consideration such soffits are shown in books upon wrong principles.

But in the following soffits, where the jambs are not parallel, they must be continued till they meet in a point, and the regulating line of the ordinates must be made to form an isosceles triangle with the jambs.

PLATE XII.

To draw the Lining of a Soffit in a straight Wall, splaying equally on all sides, with a circular Head.

In *fig. A*, continue the sides of the plan *A*, that is, *a c* and *b d*, to meet at *e*; then about the centre *e*, and from the points *a* and *c*, describe the soffit *C*, and stretch the semicircle *B* along the outline of the soffit *C*, and it will be completed.

To draw the Lining of a Soffit in a circular Wall, splaying equally on all sides, with a circular Head.

Fig. *B.*—The stretch-out of this soffit is managed the same as in the last; draw the ordinates of the semicircle *B*, from thence continue them to *f*, the concourse of the splay; and at the points *a*, *b*, *c*, *d*, *e*, where they intersect the plan, draw the parallel lines *a e*, *b f*, *c g*, &c. parallel to the base of *B*, and from the points *e*, *f*, *g*, *h*, and *i*, describe arches to *a*, *b*, *c*, *d*, and *e*, round the centre *f*, which will give the half of one edge of the soffit; the other half, being similar, is measured from it: the other edge is found in the same manner.

Note.—The ordinates of this cannot be measured from the plan as the others are, as the lines round the splay are inclined, and will therefore be longer than those on the plan.

DEMONSTRATION OF FIG. *A*.

Conceive the semicircle *B* to be turned at right angles to the plan *A*, then every point in the circumference of the semicircle *B* will be at an equal distance from the point *e*, but the soffit *C* is described with the same radius; therefore the edge of the soffit *C*, that is, the arch-line *a f*, will exactly coincide with the arch of the semicircle *B*, which was to be proved.

DEMONSTRATION OF FIG. *B*.

It is easy to conceive from the last demonstration, that if the semicircle *B* is turned up, and the soffit at *C* bent round it, the points 1, 2, 3, 4, 5, at *C*, will coincide with equal divisions in the semicircle *B*, and the points *a, b, c, d*, &c. at *C*, will fall perpendicularly over the points *a, b, c, d*, &c. in the plan *A;* for the arches *a e, b f, c g, d h*, and *e i*, at *C*, will fall over the parallel straight lines *e a; f b, g c, h d, i e*, in the plan *A*, which was to be demonstrated.

The learner is advised to cut these and the following soffits out of paste-board, and their demonstrations will be more clearly seen.

PLATE XIII.

To find the Lining of an Aperture whose plan A B C D *is a Trapezoid, with two parallel Sides* A B *and* D C, *which represent the outsides and insides of the Wall, and two equally inclined Sides* A D *and* B C, *which represent the Jambs, and whose Elevation* A I B, *on the inside of the Wall, is a Semi-ellipsis, and that on the outside,* D G C, *a Semicircle, so that a straight Edge may every where coincide with the lined Surface, and be parallel to the Horizon.*

Produce *A D* and *B C* to *E:* bisect *D C* at *F*, and draw *E F;* produce it to *I*, and it will cut *A B* at *H:* then *F G* and *H I* are equal to each other. Divide the quadrant *D G* into any number of equal parts, (as five), and draw lines through the points of division cutting the base *D C* at right angles; from the points of division, and in the same straight line with the point *E*, draw lines to cut *A H*, and the lines so intercepted will represent the level straight lines on the soffit. Make *E J* perpendicular to *E D* equal to *F G*, and mark the other divisions on *E J* from *E*, at *a, b, c, d*, respectively equal to those in *F D:* then take the distances of the several points in *D C* from *E*, beginning next *E D*, and proceeding to the last *E F*, and describe the arcs from the centres *a, b, c, d*, respectively; with the fifth part of the arc *D G* fix the foot of the compass in *D*, and cross the first arc at *e*; place one foot of the compass in *e*, cross the next arc at *f*, proceed in this manner to *i*, then *D, e, f, g, h, i*, will be the coincident line of the lining or interior covering for the arc *D G*. Join *i J* and produce it to *K;* make the angle *K J L* equal to the angle *K J E*, and make *J L* equal to *J E:* mark the divisions on *J L*, so that the distances from *J* may be equal to the distances of the several divisions on *J E*, then the other half of the plano-cuneoidal line may be found by inversion. Produce the lines *a e, b f, c g, d h, J*, &c. to

o, p, q, r, s, &c. make *e o, f p, g q,* &c. in inverted order equal to the seats of the lines on the soffits and the points *o, p, q, r,* &c. then curves being drawn through the points *o, p, q, r, s,* &c., and through *e, f, g, h,* &c. will form the wall lines of the covering, so that *A D M N* will be the whole covering or interior development.

PLATE XIV.

To find the Lining of an Aperture covered with the same Surface as in the last Plate, and terminated by a circular Wall.

Find the line *D Q M*, as in the last Plate, for a straight wall, then transfer the distances from the straight line *D F* on the plan to the arcs, as shown by *e f, g, h, i*, representing the faces of the wall to the covering, and the edges will be obtained as in the last.

PLATE XV.

To draw the lining of a cylindrical Soffit, cutting right in a Wall which does not stand perpendicular to the Ground, to a level Base. Fig. *A*.

Let *a e* at *D* be the level of the ground, *a l* the inclination of the wall, equal to the radius of the cylinder; let fall the perpendicular from *l* to *c*, in the bottom line *a e;* and draw *l e* at right angles to *l a*, cutting the level line at *e;* make the semicircle in *fig. A*, to the width of the cylinder, or the double of *a l* at *D;* take the distance *a c* at *D*, and make *b a* equal to it in *fig. A*, and describe a semi-ellipsis to the length of the large semicircle *d d*, and to the width *a b*, as shown by the small semicircle 0, 1, 2, 3, *a;* lay the equal divisions round the semicircle in *fig. A*, at *C*, along the line *d d*, on each side of the middle point 4, then take the parts *e d, d c, c b, b a*, from the plan *B*, and lay them at *D* respectively from *e* towards *d, c, b, a*, and at the points *a, b, c, d*, erect perpendiculars to *a e* to cut *l e* at *f, g, h*, and *i:* take the distances *e i, i h, h g*, and *g f*, in *D*, and lay them on the soffit at *C* respectively, from 1 *d*, 2 *c*, 3 *b*, 4 *a*, each way, then will the straight line *d d* in the soffit, when bent round, be perpendicular over the elliptic line in the plan *B*, and the curve line *d d c b a*, &c. *d*, will fall over the points *d, d, c, b, a*, in the plan: in the same manner the edge of the soffit may be brought to answer any curve line proposed.

To draw the Arches of Groins by a new Method, whether right or rampant, so that their Arches shall intersect or mitre truly together, from a given Arch of any form.

Let *fig. E* be the given arch of a Gothic form, draw the chord *a c* for one half the arch, divide it into any number of parts, (as four), and through the divisions draw lines from the centre *e* to terminate in the circumference at *h*, *g*, *l;* draw lines from *c* through *h g l* to cut the perpendicular *a d* at *b*, *c*, *d;* and if No. 2 is required to be wider, but the same height as *fig. E*, draw the two chords *a c* and *c b* for each side of the arch, divide each into four equal parts, as before, and set the parts *a b*, *b c*, *c d*, perpendicular on each end of *a b* at No. 2, and from the divisions draw lines to the vertex at *c*, then trace the curve through the points *h*, *g*, *l*, &c. so the arch at No. 2 will truly mitre into *fig. E;* in the same manner the rampant curve at No. 3 will be brought to correspond with *fig. E* and No. 2.*

PLATE XVI.

As it happens sometimes in church-work, that windows go higher than the ceiling-line, which therefore requires to be hollowed out, so that the light may be thrown down into the body of the church, I shall in this place show the method of making a curb for that purpose.

To find the form of the Curb.

Let *k b l* be the head of the window, *figure A*, and let it come as high as *a b*, above the ceiling;† and let *a b* at No. 1 be the same height, and *b c* the direction of the light, and *a c* will be the length of the curb. Make *a c* at No. 2 equal to *a c* at No. 1, and divide it into six equal parts; also divide *a b*, in *figure A*, into six equal parts, and let the ordinates be drawn as is explained in the figure; a curve being traced round the points of intersection, will give the form of the curb.

Figures *B* and *C* show the method of drawing and backing any elliptic rib

* It is hardly possible to find a more ready method in practice, because a chalk line will soon strike all the radial lines, having only to move it but once from the point *e* up to *c* at the crown; *fig. F* shows the common method—by dividing the basis of each into a like number of parts, and transferring the height, as the figures explain, at No. 1 and No. 2; nothing is more tedious in practice than raising a number of large perpendiculars, and going continually from one curve to get the height of another.

† The ceiling is here supposed to be level, which is seldom the case in a church; but the method will be nothing different if the ceiling-line *a c fig.* 1, were to incline to the horizon in any angle whatever, only observe to make *c a b* equal to that angle.

with a compass, which is exceedingly handy in drawing, and will be near enough for the representation of an elliptic rib on paper, as no other method will be so clean when done; but for practice, a trammel, or intersecting lines, is more ready.

To draw and range the Ribs by this Method.

In *B*, let *c h* be the height, and *c b* the width; divide the difference into three equal parts, and set four such parts on each side of *c*, to *d* and *d*, and make an intersection with the distance *d d* at *e*, and draw a line through *e* and *d* to *i*, then *d* and *e* are the centres for the interior side: suppose the rib is to be backed as much as *a b* upon the bottom, set *a b* from *d* to *f*, and from *e* to *g*, parallel to the base; and draw a line through *g*, *f*, to *k*; then *g* and *f* are the centres for describing the ranging lines.

The rib *E* is traced from *D*, and *a b* being set all round on the parallel lines, shows how the ranging is found for a drawing on paper: the rib *C* is described in the same manner.

The word backing is properly applied to the upper side of any thing in Carpentry or Joinery, as the back of a rafter, the back of a rail: but range applies to the operation of levelling either the upper or lower edge, and explains its own meaning, viz. forming the edge so as to range with the other edges, whether forming a ceiling or the exterior of a roof.

PLATE XVII.

DEFINITION.

Groins are formed by the intersection of arches or vaults, and the surfaces of their meeting may be considered as the sections of cylinders, cylindroids, &c.

BRICK GROINS.—Description.

P, ***P***, ***P***, &c. in the plan in *fig.* ***A***, are the piers which the vault is to stand upon; *a b*, *fig.* ***D***, is the end opening, which is a given semicircle; and *b c* is the opening of the side arch, which is to come to the same height as the end arch *a b*: fix centres over the body range, *fig.* ***A***, as shown in the section at ***C***, then board them over. In *fig.* ***A*** is the manner of fixing the jack ribs upon the boards, which likewise shows at ***C***.

To find the Mould for the Jack Ribs.

Take the openings of your arches in *fig. A*, that is *a b* and *a d*, and lay them down in *fig. D*, at *a b* and *b c*, to make a right angle. Divide one half of the given semicircle into five parts, and square them across 1, 1, 1, &c., to cut *d b* and *d c*, the diagonals, in 2, 2, 2, &c., and through the points 2, 2, 2, &c. draw lines parallel to the base of *E*, both ways towards *F* and *G*; stick in nails at 1, 2, 3, 4, 5, in the arc of *E*, and bend a thin slip of wood round them, which mark with a pencil at every nail; this slip of wood being stretched out from *d*, 1, 2, 3, 4, 5, and squared over to *G*, will intersect the other lines in small rectangles: a curve being traced through the diagonals of each rectangle, will give a mould to set the jack ribs.

To fix the Jack Ribs.

Bend the mould *G* from *a*, to the crown at *e*, in *fig. A*, which will give the edges of your boards; then fix a temporary piece of wood, (as a straight-edge, or long level), level upon the crown, in the direction of *f f*, and let it come the thickness of the boards lower than the crown, and it will give the height of the jack ribs, which is a very sure method of placing them.

To find a Mould to cut the Ends of the Boards.

The rib *F* is traced to the height of *E*, or got by a trammel, which will be fully exemplified in the following plates. Take the parts round *F*, and lay them out to 1, 2, 3, 4, 5; then *H* will be got in the same manner as *G*, which will be a mould to cut the ends of the board that goes upon the jack ribs against the body range.

Fig. I. *Is an easy method of getting the moulds when both arches are the same opening.*

Take half the opening of the arches, whatever they are, and draw a quarter circle, and divide it into six; bend a slip round it to take its parts, then stretch it out upon the base from 0 to 6, and square over the points 1, 2, 3, &c. Through the points in the arch draw the lines on both sides parallel to 0, 6; the curve being traced as before, gives both moulds of an equal and similar form.

Note. The curve *F* may be drawn in practice with a trammel independent of the other, and the two moulds *F* and *G* may be drawn separate, without any connexion of lines, as shall be shown hereafter.

PLATE XVIII.

CENTERING FOR ASCENDING OR DESCENDING GROINS.

Definition.—Groins are said to be ascending or descending when they are not built upon level ground.

The Plan and Inclination of any Groin being given, and one of the Body Ribs, as B, *also the Place of the Angles upon the Plan; to find the Form of the Side Ribs, so that the Intersection of both Arches will be perpendicularly over the Plan.*

Divide half the circumference of the given rib *B* into any number of equal parts, and draw them to intersect the angles upon the plan; and from thence let them be returned up to the rib *C*, upon the side; then *C* being measured from the given rib at *B*, as indicated by the letters, will give the form of the side centre. The same is shown at *F*, by the method of intersecting lines.

To find the two Moulds D *and* E *for placing the Jack Ribs, to bend over the Angles in the Body Range, when boarded in, so that they may be perpendicular over the Angles upon the Plan.*

At *C*, draw lines from the points *a*, *b*, *c*, *d*, *e*, *f*, *g*, &c. where the ordinates of *C* intersect the top of the arch, perpendicular to the rake, and draw the semi-ellipsis *A*, to the width of the body range, and to the height *a*, *h*, of the side centres taken perpendicular to the rake; and continue the ordinates of *B* upwards to *A*, to intersect at 1, 2, 3, 4, 5, 6. Bend a slip round these points, and mark it opposite to every point, and stretch it out along *k*, 1, 2, 3, 4, 5, 6, between *D* and *E*, and draw lines through these points, at right angles to *k* 6, to intersect with the perpendiculars. Begin at 6, and trace a curve both ways; this will give the edges of the two moulds for placing the jack ribs.

To cut the Jack Ribs to the Rake of the Groins.

Set the number of the jack ribs upon the arch *B* at their proper distances, and take their several heights, that is, *h i*, *k l*, *m n*, and set them upon the arch

G, from *a* to *b*, and from *a* to *c*, and from *a* to *d*; draw lines through these points parallel to the rake, which will show how the jack ribs are to be cut, so that they shall range properly with the other raking centres.

Note. All the body ribs must be ranged according to the rake of the groin; to do this exactly, the under edges of all the ribs must be bevelled according to the rake; then make a mould as *B*, or one of the body ribs themselves will answer instead of a mould, which being applied to each side of any other rib, keeping the bottom fair with the under edge upon each side, and drawing the curves by the other, it will give the ranging line.

PLATE XIX.

Given the two Side Arches of any ascending Groin, and the Inclination; to find the Intersection of the Angles upon the Plan.

Divide half of the body rib *B* into equal parts, and draw parallel lines to *b*, *c*, *d*, *e*, and *f*; and from the point *a*, as a centre, draw the concentric dotted circles round to *g*, *h*, *i*, *k*, *l*; then draw parallel lines to the rake, to cut the centre *C* at 1, 2, 3, 4, 5, and *a*, *b*, *c*, *d*, *e*, on the other side; and from these points let lines be drawn perpendicular through the plan. And on the centre *g* of the rib *C*, square a line up to 5, the top of the arch *C*; and from 5 draw a line perpendicular through the plan. Also through the points 1, 2, 3, 4, 5, at *B*, draw perpendicular lines to the plan the other way; begin at *h*, and trace through the angles both ways, will give the place of the groin points upon the plan.

The moulds for bending over the angles are found in the same manner as in the last plate, by taking the stretch-out round *A*, and laying it between *D* and *E*.

The reader may see such groins executed under the Adelphi Buildings in the Strand, London, where the declivity is very rapid in going to the river.

The jack ribs of the groin are cut in the same manner as directed in the last plate, and in practice there will be no occasion for tracing the angles, as the two moulds *D* and *E* are found independent of them; the reader will farther observe that the arch *B* must not be used instead of the arch *A*, which would produce a very great error in the moulds *D* and *E*, as it must be evident to every one, that the section upon the square of the cylinder, or body range, must be less in the height than the perpendicular or plumb section *B*, which in this

case is oblique: if these things are properly understood, there will occur nothing in brick groins but what may be easily surmounted.

In all kinds of brick groins the centres or body ribs must be fixed first in the same manner as if there were no side arches cutting across them; then the centres must be boarded over; then to find the place of the angles upon the boards, that is, the proper intersection of the side arches upon the plan, the moulds *D* and *E* must be both bent round the boards at one time, by keeping the points *l* and *e* of the moulds *D* and *E* upon the tops of the piers at *o* and *e*; then keep the top points together, and bend them round, keeping them still together, then the point at 5 will fall perpendicularly over *h* in the plan; round the inner edges of the moulds draw a curve upon the boards, which will be the proper intersection of the side arch. The jack ribs are cut in the same manner as directed in the last.

Note. This differs from the last Problem inasmuch as the *springings* of the side arches are *horizontal*, whereas in the last example they were all in *the line of Rake.*

PLATE XX.

The Plan of the Diagonals of any Plaster Groin, which arestraight Lines, and one of the Side Arches being given; to find the other Side Arch and Angle Rib.

Fig. 1. Case 1. If the given rib is a semicircle or semi-ellipsis, it may be described as in *fig.* 2, Plate VI. with a trammel, which is by far the readiest method; but if a proper trammel is not to be got, a temporary one may easily be made, which will answer equally well, by fixing two pieces of wood in the form of a square, that is, to make a right angle; each leg must be as long as the difference between the semi-transverse and semi-conjugate axis, and instead of the sliding nuts in the rod, two brad-awls will answer the purpose, being put through any straight slip of wood; and by moving this round either the exterior or the interior angles of the square, keeping the pins or brad-awls close to each leg, it will describe one quarter of an ellipsis at one time.

To find the Length of the Jack Ribs.

Lay down the plan of the ribs, as at *B*, and draw a rib upon each opening; then draw perpendicular lines from the plan of each opening, at the extremities

a c e, to cut its corresponding ribs at *b*, *d*, *f*: then the distance from *b* to *b* shows the length of the first jack rib, from *d* to *d* the length of the second, and from *f* to *f* the third.

To bevel the Angle Ribs, so that they shall range with each opening of the Groin.

First get the ribs out in two halves or thicknesses, as at ***E*** and ***F***, then draw the plan of your angle rib which is placed between ***E*** and ***F***, and it will show the true ranging upon the bottom of the rib; then shift your hip mould parallel upon the base of ***E*** and ***F***, which will show how much wood there is to be taken away; then nail the two halves together, and the rib will be completed.

METHOD I.

Fig. 2. Case 2. When the given rib is a segment of a circle, or any other curve whatever, the ribs will be described as in Plate XV. *fig.* ***E***, as are shown at ***B***, ***E***, and ***F***.

METHOD II.

When the given arch is a segment of a circle as at ***A***, take its height *b c*, and place it from *b*, the centre of the groin to *c* at ***C*** and ***D***; then take the whole diameter of the arch ***A***, that is, twice the radius *a c*, and place it from the crown of the other arches perpendicular to their bases from *c* to *b* at ***C***, and from *c* to *d* at ***D*** (which represents the Angle Rib); then the arch may be drawn as in Plate VIII. by intersecting lines; the ranging of the ribs is done in the same manner as in the last groin.

Either of these two methods is much readier in practice than tracing the ribs through ordinates.

PLATE XXI.

*Given one of the **Body Ribs**, and **Plan**, and **Angle** of the **Ascent** of a **Groin** not standing upon level **Ground**; to find the **Form** of the ascending **Arches**, and the **Angle Ribs**.*

Let *b a c* at ***B*** be the angle of the ascent; from the point *b* make *b c* perpendicular to *a b*, and describe the curve ***B***, as in Plate XV. (at No. 3, in *fig.* ***E***;) then draw the diagonal *a b* at ***E***, and make *b c* perpendicular to it, and equal to *b e* at ***B***; then draw the hypothenuse *a c*, and describe the angle rib ***E***, in the same manner as that of ***B***.

To find the Length of the Jack Ribs, so that they shall fit to the Rake of the Groin.

Draw lines up from the plan to the arch, as at *D*, in the same manner as is explained in the last plate; then the arch from *a* to *a* is the first jack rib, from *b* to *b* the second, and from *c* to *c* the third, &c.

To range the Angle Ribs for such Sort of Groins.

Get the ribs out in two halves, as in the last plate, then the bottom of the ribs must be bevelled agreeable to the ascent of the groin, and the plan of it must be drawn upon the level, and from thence they may be drawn perpendicular from the plan to the rake of the rib; then take a mould to the form of the rib, or the rib itself, and slide this agreeable to the rake, to the distance that is marked upon the bottom to be backed off, which will show how much the rib is to bevel all round.

PLATE XXII.

OF GROINS CUTTING UNDER PITCH.

Definition.—When the side arches of a groin are lower than the body arch, then they are called under pitch groins.

Given one of the Body Ribs B, *and the Height* f g, *of a Door or Window, &c. and its Width* m l; *to find the Side and Angle Ribs* D *and* E, *so that the Intersection of the Side Arch* D *with the Body Rib* B, *shall be straight upon the Plan.*

Draw *c e* perpendicular to *c b*, the base of *B*, and equal to the height of the window at D, that is, equal to *f g*; through *e* draw *e a* parallel to *c b*, cutting the arch *B* in *a*; let fall the perpendicular *a b* to *c b*, and continue it so as to cut the line *f g* in *D* produced to *k*, and draw *k m* and *k l*, which is the place of the angles upon the plan, or the base of the angle ribs; then the ribs *D* and *E* may be described from the given rib F, as directed in plate XV. *fig. E*, from a centre; or they may be described as at *fig. F* of the same plate, as you see on the other side at *A* and *C* by ordinates: but the first is by far the easiest method for practice, for if you stick a pin or brad-awl in *g*, at *D*, and lay a chalk line to it, you may strike all the radial lines *g* 1, *g* 2, *g* 3, *g* 4, &c., in much less time than the parallel lines in *A* and *C* can be drawn, and with much greater accuracy: and

the divisions upon *c n* of the arch *F*, may be marked upon a rod, and readily transferred to the arches *D* and *E*, on *m p* and *f g:* then move your brad-awl out of *g*, and stick it in the crown at *f*, and strike lines from the divisions of *m p* to cross the other lines, which will give the points through which the arch must pass: but the reader must recollect that four or five points will not be sufficient in the practice for tracing a large curve with accuracy, and therefore a greater number must be found. At the other end of the groin is shown the manner in which it may be fixed, sufficiently intelligible for a workman.

PLATE XXIII.

A CYLINDRO-CYLINDRIC ARCH.

DEFINITON.

A cylindro-cylindric arch, or Welsh groin, is an under pitch groin, whose side and body arches are both given semicircles, or they may be similar segments of circles cutting through one another, whose intersections do not meet in a plane surface, that is, the place of the ribs will not be straight upon the plan, but will generate a curve line.

Given the Body Rib A, *and the Side Rib* B, *of a Cylindro-Cylindric Arch, to find a Mould for the intersecting Ribs.*

Divide half the arch *B* into any number of equal parts, 1, 2, 3, *d*, or they may be taken at discretion, and from these points let fall perpendiculars to *a b*, its base; produce them at pleasure; also from the same points 1, 2, 3, *d*, draw lines parallel to *a b*, the base of *B*, to intersect the perpendicular line *e f*; transfer the divisions from *e f* to *e g* by a series of concentric circles; then from the divisions of *e g* draw lines parallel to *p q*, to intersect the body rib *A* at the points *h*, *u*, *w*, *y*; from these points draw perpendiculars to *p q*, its base, and continue them to intersect with the perpendiculars from *B*, at the points *k*, *l*, *m*, *n*, between *C* and *D*; then trace a curve through these points, which will be the place of the intersecting ribs upon the plan; then draw two other curve lines on each side of *k*, *l*, *m*, *n*, &c. to make the thickness of the rib upon the plan; on the inside of the curve draw two chords for each half to their extremities, draw two other lines parallel to them to touch the outside curve, then the distance between those two straight lines will show what thickness of stuff it will take to make the intersecting rib; through the points *k*, *l*, *m*, *n*, &c. draw perpendicular lines to the chords; make the heights *c d*, 3 3, 2 2, 1 1, &c. at *D*, equal to their corresponding

heights at *B*: then *D* is the mould for the intersecting rib; *C* is the same as *D*, but on different sides of the rib.

To range the Ribs, so that they will stand perpendicular over the Plan.

At the points *x*, *v*, *t*, *i*, in the base of *A*, draw the parallel dotted lines to the ordinates of *C* and *D*, and make their corresponding heights equal to those of the arch *B* or *A*; draw the dotted curve line *h u w y* at *C*, and it will show how much is to be bevelled off on that side of the rib; in like manner the other side *D* is bevelled.

To find a Mould to bend under the intersecting Ribs, so that it shall give the Place of the Angle truly upon the Plan.

Take the stretch-out round the under side of the rib *D* at the dots, by bending a thin slip of wood round it; mark it at each dot, and stretch it out along the straight line *b c* at *E*, draw the ordinates across, and prick them from the plan that lies between *D* and *C*; then *E*, agreeable to the letters, will be the mould required.

Note.—The straight edge of the mould must be kept exactly to the face of the rib; when it is bent round, then draw a curve round the under side of the rib, by the other edge of the mould, which will give the true place of the angle.

PLATE XXIV.

There will be no occasion for explaining the lines of this groin, as they are of the same nature as those in the last plate; but it will be proper to take notice, as this is a bevel groin, the ribs must lie in the same direction as the plan of the groin, which will make them longer than their corresponding given arches at the top, although of the same height; they are consequently ellipses, being the sections of cylinders, therefore to make a rib over *l m*, across the two piers, take the extent of the base *l m*, and the height of the given arch *n o*, and describe an ellipsis; and to describe the side arches between any two piers, as from *a* to *b*, take the extent *a b*, and the height of the given arch, *p g*, at *A*, and describe an ellipsis, it will give the proper form of the rib to stand over *a b*; the intersecting ribs will require two moulds, *C* and *D*, owing to the groins being bevel upon the plan.

Note. The letters are marked the same upon *D* and *C* as they are upon *E*, to show they are traced from it.

PLATE XXV.

To describe the intersecting or Angle Ribs of a Groin standing upon an octagon Plan, the Side and Body Ribs being given both to the same Height.

Fig. 1. *E* is a given body rib, which may be either a semicircle or a semi-ellipsis, and *A* is a side rib given of the same height; *D* is a rib across the angles, traced from *E*, (the basis of both being divided into a like number of equal parts): divide the base of the given rib *A*, into the same number of parts; from these points draw lines across the groin to its centre at *m*, and from the divisions of the base of the other rib *D*, draw lines parallel to the side of the groin, then trace the angle curves through the quadrilaterals, which will be the place of the intersecting ribs; draw the chords *a b* and *b c*, then prick the moulds *B* and *C* from *E* or *D*, but take care not to set them from the crooked line at the base, but from the straight chords *a b* and *b c*.

To describe and range the Angle Ribs of a Groin circular upon the Plan, the Side and Body Arches being given, as in the last Groin.

The ribs are described in the same manner as in the last example for the octagon groin, or in the same manner as the cylindro-cylindric, Plate XXIII. and the ranging is found in the same manner as is described in that Plate.

Note. *E* and *F* are the same moulds as are shown at *B* and *D*.

PLATE XXVI.

The Side Rib A, *and the Angles being given straight upon the Plan, to find the Angle Rib* G, *and the Body Rib* C.

Let the rib *A* be supposed to be placed over the straight line *a b*, as its base, which divide into any number of equal parts, as eight; from the points of division draw lines to the centre of the groin to intersect the angles at *a*, *b*, *c*, *d*, *e*, *f*, *g*,

these points will give the perpendiculars of the ordinates of *G*, which being made respectively equal to those of *A*, will give the curve of the rib *G*. If from the points *a*, *b*, *c*, &c. arcs be drawn from the centre of the groin to intersect the base of *C*, at 1, 2, 3, 4, 3, 2, 1, and perpendiculars be drawn and made correspondingly equal to those of *A*, and *C* be traced through these points, then *C* will be the body rib.

To describe the Ribs of a Groin over Stairs upon a circular Plan, the Body Rib being given.

Fig. 2. Take the tread of as many steps as you please, suppose nine, from *E*, and the heights corresponding to them, which lay down at *F*; draw the plan of the angles as in the other groins, and take the stretch round the middle of the steps at *E*, and lay it from *a* to *b* at *F*; make *d e* perpendicular to *d c* at *B*, equal to *d e* at *F*; draw the hypothenuse *e c*, draw perpendiculars from *d c* up to *B*, and set off *B* from *A*, as the figures direct, then *B* is the mould to stand over *a b*; draw the chords *a* 4 and 4 *m* at the angles, make *a g*, 4 *h*, perpendicular to them, each equal to half the height *d e*, at *B* or *F*, draw the hypothenuse *g* 4, and *h m*, draw the perpendicular ordinates from the chords through the intersection of the other lines that meet at the angles, then trace the moulds *D* and *C* from the given rib *A*, which will form the moulds for the angle or intersecting ribs.

Note. The reason that the angle ribs *D* and *C* are laid contrary ways, is only to avoid confusion.

It must be borne in mind that the great difference between these two species of groins consists in this; some are governed by the *sweep* of the groin, in which case the line of intersection on the plan is *curved*, (except where both are level, and of equal opening); the other, where the lines of intersection are designed as *straight lines upon the plan*, in which case the arches are *rampant*, or the two halves are of different curves, and the solutions are drawn from the Problems in Plate XV. In one case, the *plan* is adapted to the sweep of the arch—in the other, the *arch* is governed by the *plan*.

PLATE XXVII.

As all the sections of a sphere are circles, and those passing through its centre are equal, and also the greatest which can be formed by cutting the sphere; it is therefore evident that if the head of a niche is intended to form a spherical surface, the most eligible method is to make the plane of the back ribs pass through the centre; this may be done in an infinite variety of positions, but perhaps the best and that which would be easiest understood is to dispose them in vertical planes. If the head is a quarter of a sphere, the front rib, and the plate or springing, on which the back ribs stand, will curve equally with the vertical ones; but if otherwise, they will be portions of less circles. But it is evident if the front and springing ribs are intended to be arcs *less* than those of semicircles, either equal to each other or unequal, that, as they are posited at right angles to each other, there can be only one sphere which can pass through them; consequently if the places of the vertical ribs are marked on the plan, these ribs can have only one curve: in the former case no diagram is necessary, but in the latter it may be proper to show how the vertical ribs and their situation on the front rib are found.

To get out the Ribs for the Head.

From the centre *C* draw the ground plan of the ribs as at *fig. A*, and set out as many ribs upon the plan as you intend to have in the head of the niche, and draw them all out towards the centre at *C*. Place the foot of the compass in the centre *C*, and from the ends of each rib, at *e* and *c*, draw the small concentric dotted circles round to the centre rib at *m* and *n*; and draw *m g* and *n i* parallel to *r k*, the face of the wall; then from *q* round to *c* upon the plan, is the length and sweep of the centre rib, to stand over *a b*; and from *i* round to *e*, the length and sweep of the rib that stands from *c* to *d* upon the plan; and from *g* round to *e* is the sweep of the shortest rib, that stands from *e* to *f* upon the plan.

Secondly. To bevel the Ends of the Back Ribs against the Front Rib.

The back ribs are laid down distinct by themselves at *C*, *D*, and *E*, from the plan. Take *c* 1, in *fig. A*, and set it from *c* to 1 in *D*, which will give the bevel of the top of the rib *D*. And from *fig. A*, take from *e* to 2 upon the plan, and set from *e* to 2 in the rib *E*, which will give the bevel of the top.

Thirdly. To find the Places of the Back Ribs where they are fixed upon the Front.

From the points *a*, *c*, and *e*, at the ends of the ribs, in the plan, *fig. A*, draw

the dotted lines up to the front rib, to *d f* and *w* in B, which will show where they are to be fixed upon the front rib. The double circle upon the front rib shows the ranging.

PLATE XXVIII.

To find the Curve of the Ribs of a spherical Niche, the Plan and Elevation being given Segments of Circles.

In *fig. A* is the elevation of the niche, being the segment of a circle whose centre is *t*; at *B* is the plan of the same width, and may be made to any depth, according to the place it is intended for, and its centre is *c*; on the plan *B*, lay out as many ribs as it will require; draw them all tending to the centre at *c*, they will cut the plan of the front rib in *g*, *f*, *e*, *d*; through the centre *c*, draw the line *m n*, parallel to *a b*, the plan of the front rib; put the foot of your compass in the centre at *c*, draw the circular lines from *a*, *g*, *f*, *e*, *d*, to the line *m n*, and make *c s* equal to *u t*; that is, make the distance from the middle of the chord line *m n* to *s*, (the centre of the arch at *C*,) equal to the distance from the middle of the chord at the top (at *fig. A*,) to its centre at *t*; then place the foot of your compass in *s*, as a centre, and from the extremities *m* or *n*, describe the arch at *C*; with the same centre draw another line parallel to it, to such breadth as you intend your ribs shall be; then *C* is the true curve of all the back ribs in the niche.

Note.—The points *l*, *k*, *i*, *h*, show what length of each rib will be sufficient from the point *m*; from *h* to *m* is the rib that will stand over *d x*, from *i* to *m* is the rib that will stand over *e u*, from *k* to *m* over *f v*, and from *l* to *m* over *g w*: the other half is the same.

Through the centre *t*, draw D E, parallel to *a b*; complete he semicircle E F G D, then D E is the diameter; through *n* draw *n* A parallel to *u d*; from the centre *t*, with the distance *t* A describe another semicircle, whose diameter is C B; then will the semicircle C M G A B be equal to a vertical section of the globe, standing on K I, passing through its centre at *c*, which is the same curve as the rib at *C*, because *u* A is equal to *c n*, and *c s* bisecting *m n* at right angles, is equal to *t u*, bisecting E A at right angles; therefore the hypothenuse *t* A, that is, the radius of the circle B A M E C, is equal to *s m* or *s n*, the radius of the circle or rib at *C*.

PLATE XXIX.

The Plan of a Niche in a circular Wall being given, to find the Front Rib.

B is the plan given, which is a semicircle whose diameter is *a b*, and *a, i, k, l, m, h*, the front of the circular wall; suppose the semicircle *B* to be turned round its diameter *a b*, so that the point *v* may stand perpendicular over *h* in the front of the wall, the site of the semicircle standing in this position upon the plan will be an ellipsis; therefore divide half the arch of *B* upon the plan into any number of equal parts, as five; draw the perpendiculars 1 *d*, 2 *e*, 3 *f*, 4 *g*, 5 *h*; from the centre *c* with the radius *c h*, describe the quadrant of a smaller circle, which divide into the same number of equal parts as are round *B*; through the points 1, 2, 3, 4, 5, draw parallel lines to *a b*, to intersect the others at the points *d, e, f, g, h*, through these points draw a curve, it will be an ellipsis; then take the stretch-out of the rib *B*, round 1, 2, 3, 4, 5, and lay the divisions from the centre both ways at *F*, stretched out; take the same distances *d i, e k, f l, g m*, from the plan, and at *F* make *d i, e k, f l*, on both sides equal to them, which will give a mould to bend under the front rib, so that the edge of the front rib will be perpendicular to *a, i, k, l, m*.

Note.—The curve of the front rib is a semicircle, the same as the ground-plan, and the back ribs at *C, D*, and *E*, are likewise of the same sweep.

The reason of this is easily conceived; the niche being part of a globe, the external surface curvature must be everywhere the same, and consequently the ribs must fit that curvature.

Note.—The curve of the mould *F* will not be exactly true, as the distances *d i, e k, f l*, &c. are rather too short for the same corresponding distances upon the soffit at *F;* but in practice it will be sufficiently near for plaster work; but those who would wish to see a method more exact, may examine Plate XV. *fig. A*, where *C* is the exact soffit that will bend over its plan at *B*.

In applying the mould *F* when bent round the under edge of the front rib, the straight side of the mould *F* must be kept close to the back edge of the front rib, and the rib being drawn by the other edge of the mould, will give its place over the plan.

PLATE XXX.

The Plan and Elevation of an Elliptic Niche being given, to find the Curve of the Ribs.

FIG. *A.* Describe every rib with a trammel, by taking the extent of each base from the plan whereon the ribs stand to its centre, and the height of each rib from its height at the top of the niche, which will give the true sweep of each rib.

To back the Ribs of the Niche.

There will be no occasion for making any moulds for these ribs, but make the ribs themselves; then there will be two ribs of each kind; take the small distances 1 *e*, 2 *d*, from the plan at *B*, squaring each point across the rib as is therein shewn, and put it to the bottom of the ribs *D* and *E*, from *d* to 2, and *e* to 1; then the ranging may be drawn off by the other corresponding rib; or with the trammel, as for example at the rib *E*, by moving the centre of the trammel towards *e*, upon the line *e c*, from the centre *c*, equal to the distance 1 *e*, the trammel rod remaining the same as when the inside of the curve was struck.

Given one of the common Ribs of the bracketing of a Cove, to find the Angle Bracket for a rectangular Room. FIG. F.

Let *H* be the common bracket, *b c* its base; draw *b a* perpendicular to *b c*, and equal to it draw the hypothenuse *a c*, which will be the place of the mitre; take any number of ordinates in *H*, perpendicular to *b c*, its base, and continue them to meet the mitre line *a c*, that is, the base of the bracket at *I;* draw the ordinates of *I* at right angles to its base; then the bracket at *I*, being pricked from *H*, as may be seen by the figures, will be the form of the angle rib required.

Note.—The angle rib must be ranged either externally or internally, according to the angle of the room.

Having given a common Bracket K, FIG. G, *for a Plaster Cornice, to find the Mitre Bracket,* L.

Proceed as in the last example, and as is shewn in the Plate, and you will have the bracket required.

Division A.

SUPPLEMENT.

PRACTICAL MATHEMATICS, MENSURATION, ETC.

PRELIMINARY REMARKS.

OUR object in offering this Work to the Public has been to afford a good book, of sound practical utility, to the most important part of the Building trade —the Carpenter. And while we are sensible that great changes are now made, and have been in progress for some time past, in this art, we are not forgetful of the old works which have preceded these changes, and which in their original constitution contain elements which can never become obsolete, and must always be studied and understood before any excellence can be attained in this most important branch of the arts of Construction. For this reason, as our readers are aware, we have made the original work of the justly celebrated Peter Nicholson the basis of the principal branch of our undertaking; and we trust, in this our supplementary matter, and in our other divisions of the subject, to add such modern inventions, such new developments of fancy and taste, and such productions of the bolder styles of construction, as the gigantic undertakings of the present era daily call forth; and that this Work will be acknowledged as one of the most complete and useful books ever given to the Carpenter. But this consideration forces itself upon us; that a high and perhaps over-refined scientific tone pervades the nomenclature and the details of almost all modern works, which the practical man has not time nor leisure to enter into; and yet that the progress in all sorts of knowledge, and the necessity of keeping pace with that progress, compels him to feel that he is excelled in his own branch by men never educated therein. In short, that the vast labors of the Civil Engineers are fast causing them to excel all other branches of the constructive arts.

For some time past it has been the case that men of science seemed to throw all the difficulties in the way of students that they could: and where time is of no object there is some wisdom in this course; for as in athletic arts severe training is necessary to excellence, so in the mental sciences the severer the impediment which is surmounted, the more vigorous the mind and memory become; the more piercing and correct the analytic faculties; the sounder and abler the scholar is in every point. But this is only well for men of leisure. In cases where we have to deal with men of active minds, and absorbing daily avocations, we must pursue the contrary course. All difficulties must be lessened, all labor abridged, and every pains taken to sweeten and shorten the way to the desired end.

To sum up in short, it is now necessary that every man should know many things that were of little use to his predecessor; and as time now is so precious, and leisure so scarce, to what it was in the days of our forefathers, it is equally necessary to find the shortest and plainest methods of imparting this knowledge.

One change, and a most important one, is the rapid increase of the system of calculation by Decimals. It is partly owing to the free intercourse with the continent. The Civil Engineers calculate their cubic and lineal measurements wholly by decimals. Their tapes, rules, and height staves, are all graduated decimally; their little books of useful formulæ are all so expressed; the system is so widely extending, that no person ought to be unacquainted with it. There is also great probability that the same system will be introduced for our weights and measures, and even into our coinage. The word "decimal" has been a sort of bugbear to the student, and considered to express something very abstruse and difficult. We trust to be able to afford our readers a simple and easy method by which a key may be afforded to both Fractional and Decimal calculations, and that by a little attention they may be proficients in both.

And these are the branches of knowledge which lead to perhaps the most useful of all, *Mensuration*. We hope to give in a few following pages a key to all the best problems in this branch of science, so expressed that the practical man may easily and speedily make himself master of them. We hope to enable the Carpenter to maintain his present rank among the artisans of this industrious country, making way, on the one hand, against the encroachments of machinery, and on the other, against the rivalry of other branches of mechanical ingenuity.

With this view we shall commence, first, with the practice of Fractional and Decimal calculations. We shall then give a series of problems in Practical Geometry, as supplements to Nicholson's excellent work (which will still be

continued with the other branches), and shall then, as may seem most suitable, give with them the most useful practical problems in Mensuration.

FRACTIONS.

DEFINITIONS, &c.

(1.) A *fraction* is a quantity that represents a part or parts of some whole matter or number; as $\frac{1}{4}$, which is one fourth part; or $\frac{3}{4}$, which is three of such fourth parts of some whole number or quantity.

(2.) The whole matter or number is commonly called *an integer*, and is supposed to be divisible into any number of parts at will.

(3.) A *simple fraction* consists of two parts, divided by a straight line; as $\frac{5}{6}$. The lower part (6) is called the denominator, and shows into how many equal parts the whole matter or integer is divided; namely, 6. The upper (5) is called the numerator, and shews how many parts out of the six are to be taken, namely, 5. The fraction is read five-sixths.

(4.) A *mixed number* consists of a whole number and a fraction; as $3\frac{3}{5}$.

(5.) A *proper fraction* is one whose numerator is less than the denominator; as $\frac{3}{5}$.

(6.) An *improper fraction* is one whose numerator is either equal to (as $\frac{5}{5}$), or greater than its denominator, (as $\frac{18}{5}$). If equal, the fraction represents the integer, or 1; five-fifths of course being the whole.

(7.) A fraction always represents the division of the numerator by the denominator, as $\frac{3}{4}$ is three integers divided by four; $\frac{18}{5}$, 18 integers divided by 5.

(8.) Any number may be expressed as a fraction by making the denominator unity; as $\frac{5}{1}$ is 5.

(9.) Any *improper fraction* may be reduced to a mixed number by dividing the numerator by the denominator, and placing (after the quotient) the remainder

over the denominator as a new numerator, and forming a mixed number; thus, $\frac{18}{5}$, 5 into 18, equal 3 and 3 over, or $3\frac{3}{5}$. It was supposed an *improper* way of expression to say $\frac{18}{5}$, instead of $3\frac{3}{5}$, whence its name.

(10.) A *compound fraction* is the fraction of a fraction, as $\frac{1}{2}$ of $\frac{3}{4}$; $\frac{1}{4}$ of $\frac{5}{6}$ of $\frac{7}{10}$.

(11.) If *both* the numerator and denominator be multiplied or divided by the same number, the actual value is not changed: thus $\frac{1}{2}$ multiplied by 2 is $\frac{2}{4}$, and two fourths, or two quarters, is of course one-half; so $\frac{3}{6}$ multiplied by 3 is $\frac{9}{18}$, exactly equal in value; so $\frac{2}{4}$ divided by 2 is $\frac{1}{2}$, and $\frac{9}{18}$ divided by 3 is $\frac{3}{6}$.

We shall now proceed to describe the signification and use of the mathematical signs or symbols. They are now so very extensively adopted, are so very convenient, and simplify matters so much when learned, that we propose to use them frequently in this work; and the learner must not be frightened at them, as we are sure, after two or three evenings' attention, they will become familiar and easy to every one, and the learner will thank us for giving him so short and clear a method of describing what he means.

(12.) The sign + or *plus*, is the sign of addition, and signifies that the quantity placed after it must be added to the other, as $12 + 10$ is ten added to twelve.

(13.) The sign — or *minus*, is the sign of subtraction: thus $12 - 10$ is ten deducted from twelve.

(14.) Where several numbers follow one another, as $10 - 2 + 6 - 3$, the numbers marked + must be added together, and also those marked —, and the difference between the two sums taken: thus -2 and -3 must be added together, making 5; and 10 and $+6$ making 16; then 5 deducted from 16 leaves 11. Any number standing first or alone without mark is supposed to have the sign +; thus in our example, 10 is supposed to be $+10$; and the whole might be written $+10 + 6 - 2 - 3$.

(15.) The sign $\times$ or *into*, is the sign of multiplication, and signifies that the quantities between which it stands must be multiplied into each other, as 2×3 signifies two into or multiplied by three, equal to 6; and $3 \times 10 \times 5$ equal to 150. In the higher mathematical calculations it is usual to substitute a simple point (.)

for the sign $\times$; thus $3 \times 10 \times 5$ is written 3.10.5; but as the point (.) in general shews the place of the decimal, we shall always use the $\times$ as a mark of multiplication.

(16.) When any quantity is multiplied into itself, the number of times in which such operation is performed is shewn by a small figure placed above the integer on the right-hand side; thus 4^1 means simply 4; 4^2 means 4 multiplied once into itself, or 4 times 4, or 16, and is usually called 4 squared. 4^3 means 4 multiplied into itself 3 times: thus 4 times 4 is 16, and 4 times 16 is 64, and is usually called 4 cubed. 4^4 means 4 multiplied four times, as 4 times 4 is 16, 4 times 16 is 64, and 4 times 64 is 256, and is called 4 to the fourth power; and so on to the 5th, 6th, &c. &c. powers.

(17.) The sign $\div$ *divided by*, signifies that the former of two quantities is to be divided by the latter; thus $12 \div 2$ signifies 12 divided by 2, or 6; $18 \div 5$ is 18 divided by 5, or (see Nos. 6 and 7) $3\frac{3}{5}$. Division is also expressed fractionally by placing the sum to be divided as a numerator over that by which the division is to take place, as a denominator; thus $\frac{18}{5}$ is the same as $18 \div 5$.

(18.) The sign $=$ *equal to*, signifies that the quantities between which it is placed are equal to one another, as $10 + 2 - 4 = 8$, signifies the result of the addition and subtraction to be *equal to* 8; $4 \times 3 = 12$, shews the similar result of the multiplication; $4^3 = 64$, signifies that the triple multiplication of 4 is *equal to* 64.

(19.) As numbers multiplied into themselves signify the squares, cubes, &c. of such numbers, so it is often very necessary in Mensuration to discover what sums thus multiplied *have* formed the sum in question; and this number is called the root of the number given; thus 3 is the second or square root of 9; and 4 is the third or cube root of 64; as has been shewn above. This is usually expressed by the mark $\surd$, signifying the *square root* of any number, as $\surd 16 = 4$; or by placing a small figure over the mark, it will show the number of times the multiplication has been made, and the degree to which it must be reduced: thus $\sqrt[3]{64} = 4$, or the third or cube root of 64 is equal to 4; so $\sqrt[4]{\ }$ signifies the biquadrate or fourth root; thus $\sqrt[4]{81} = 3$, or the fourth root of 81, is equal to 3; and so on of the 5th, 6th, &c. &c. roots.

(20.) The *proportion* between numbers is shewn by points (: ::); thus

$6 : 3 :: 4 : 2$; or six is to three (or bears the same ratio to three) that four does to two. All rule of three sums may be thus expressed.

(21.) A quantity is said to be a *measure* of another when it is contained in the other a certain number of times exactly, without remainder: thus 6 is a measure of 12, because it is contained twice therein with no remainder; 20 is a measure of 100, because it is contained 5 times exactly therein; but 20 is no measure of 98, because it cannot be divided by it exactly without a remainder.

(22.) A quantity is said to be a *multiple* of another when it contains it a certain number of times exactly when multiplied; thus 12 is a multiple of 6, because it is contained therein twice, or $6 \times 2 = 12$; and 100 is a multiple of 20, because $20 \times 5 = 100$ exactly and without remainder.

As the words *measure* and *multiple* are of very common use, a familiar illustration may not be amiss. Thus, a rod 4 feet long would be a *measure* of 96; because it may be turned over 24 times, and will end exactly at the 96th foot without remainder; but it would not be so of 98, because there would be half the rod to spare after turning it over 24 times.

So again, 10, 15, 25, 60, are all *multiples* of 5, because $5 \times 2 = 10$; $5 \times 3 = 15$; $5 \times 5 = 25$; and $5 \times 12 = 60$.

(23.) If two or more numbers are placed between ( ) or have a line drawn over them, it signifies that they should be taken *collectively*, and are said to be within a *vinculum* or chain. Thus $\overline{2+4} \times 2$, or $(2+4) \times 2$ means $2+4$, or 6, multiplied by $2 = 12$; but $2+\overline{4 \times 2}$ means 2 added to (4 multiplied by 2) or 8, and is $2+8=10$.

QUESTIONS FOR PRACTICE.

[1.] Write in ordinary words $7+8-6+10$, and shew the result.

[2.] The same with $1001+22-339-22-41+718$.

[3.] Express by signs 10 added to 7, then 3 deducted, 12 added, and 9 deducted, and shew the result as above.

[4.] The same, 3002 added to 19, and then to 331 ; deduct 478, and also 92, and add 573, and deduct 45 and 39.

[5.] How would you express the result of $491 - 763 + 42 + 19 - 374$?

[6.] The same of $- 7854 + 31092 - 26066 + 312 + 999$.

[7.] Write in ordinary words $6 \times 5 \times 10 \times 22 =$; and shew the result of this multiplication after the sign of equality.

[8.] The same with $33 \times 21 \times 718 \times 9 =$.

[9.] Express by signs 29 multiplied by 36, then by 4, then by 523, and shew to what sum it is equal.

[10.] The number 12 is to be multiplied into itself 3 times; express this by the proper sign, and state the mathematical phrase for this operation.

[11.] The number 9 is multiplied into itself, the product is again multiplied by 9, then again, then again; express these operations by the proper signs and proper phrases.

[12.] Write in ordinary words $3112 \div 51$; $793 \div 22$; $4192 \div 17$.

[13.] Why can $7 \div 33$ be written $\frac{7}{33}$?

[14.] Express by signs 10 divided by 5; 11 divided by 33; 4786 divided by 222; and also write the same fractionally.

[15.] The number 14 multiplied once into itself is equal to 196; and this result also by $14 = 2744$. What is the square root of 196; and what is the cube root of 2744; and express these results by the proper signs?

[16.] Write in the ordinary manner $899^2 = 808201$; $151^2 = 22801$; $\sqrt{50176} = 224$; $\sqrt[3]{531441} = 81$.

[17.] The same $155^2 = 24025$; $999^2 = 998001$; $\sqrt{961} = 31$; $\sqrt[3]{729} = 9$.

[18.] Express by signs 6 squared; 9 cubed; 713 to the fourth power; the square root of 1714; the cube root of 999; the fourth or biquadrate root of 10033.

[19.] $8 \times 8 = 64$; $64 \times 8 = 512$; $512 \times 8 = 4096$. Express these by the signs of the different powers.

[20.] Write in ordinary words $9 : 81 :: 27 : 243$; $14 : 7 :: 1000 : 500$.

[21.] Express by signs, as 30 is to 120, so is 120 to 480. As 729 is to 9, so is 81 to 1. As 6 is to 36, so is 36 to 216.

[22.] Shew the difference between $\overline{13 \times 2} + 21$, and $13 \times \overline{2 + 21}$; also $(6+3+4+2) \times 5$ and $(6+3+4)+(2 \times 5)$; also $\overline{7 \times 10} + 7$, and $7 \times \overline{10+7}$; and shew all the results after a sign = or equality.

[23.] Shew by signs the difference between 99 added to 9 and multiplied by 81, and 99 multiplied by 9 added to 81, and express the different results after a sign = as in the former cases.

The first thing necessary to be learned in Fractional Arithmetic is what is usually called the ***Reduction of Fractions;*** but as it frequently happens that in the course of this operation some fractions have to be *increased* in apparent amount for the purposes of simplifying their ultimate form, we think it will be better to call this branch of our subject

THE CONVERSION OF FRACTIONS.

(24.) To convert a whole number or integer into a fraction with a given denominator:

Multiply the proposed number by the given denominator, make this the numerator, and place the given denominator below it.

Thus, convert the number 9 into a fraction whose denominator shall be 5. Now $9 \times 5 = 45$. Therefore the fraction is $\frac{45}{5}$. See (11.)

(25.) To convert a mixed number to an improper fraction:—or, in other words, to *merge* the integral part *into* the fraction:

Multiply the integral part, that is, (as has before been explained) the whole number, or integers, which stand at the left hand of the fractional part, by the denominator of such fractional part: add the numerator thereof to the product, make this last sum the new numerator, and keep the original denominator.

Thus, convert $3\frac{3}{5}$ into an improper fraction; then $(3 \times 5) + 3 = \frac{18}{5}$. See (9.)

Also convert $19\frac{7}{10}$ into an improper fraction; then $(19 \times 10) + 7 = \frac{197}{10}$. Or in ordinary figures:

$$\begin{array}{r} 19 \\ 10 \\ \hline 190 \\ 7 \\ \hline 197. \end{array}$$

Place this above the denominator for a new numerator; $\frac{197}{10}$.

(26.) To convert an improper fraction to a mixed number; this is the reverse of the last operation, and in fact is in other words to *separate* the integer *from* the fractional part:

Divide the numerator by the denominator, put down the quotient for the integer, and place the remainder over the denominator for a new numerator.

Thus, convert $\frac{197}{10}$ to a mixed number; 197 divided by 10 is 19 and 7 over; then the fraction is $19\frac{7}{10}$.

Convert $\frac{14534}{21}$ to a mixed number; then

$$\begin{array}{l} 21)\ 14534\ (692 \\ \quad\ \ 126 \\ \quad\ \ \overline{\ 193} \\ \quad\ \ \ 189 \\ \quad\ \ \ \overline{\ \ 44} \\ \quad\ \ \ \ \ 42 \\ \quad\ \ \ \ \overline{\ \ 2} \text{ Rem.} \end{array}$$

Or in mathematical signs $14534 \div 21 = 692 + \overline{2 \div 21}$, and therefore the improper fraction is $692\frac{2}{21}$.

(27.) To convert a compound fraction to a simple fraction :

Multiply all the numerators together for a new numerator, and all the denominators for a new denominator.

Thus $\frac{1}{2}$ of $\frac{2}{3} = \frac{2}{6}$; $\frac{2}{3}$ of $\frac{3}{4}$ of $\frac{5}{6} = \frac{30}{72}$. To make this rule clear, it is necessary to anticipate a part of one branch of our subject, and explain the method of multiplying and dividing a fraction by a number. The rules are:

To multiply any fraction by a *whole number*; multiply the *numerator* by that number, and retain the *denominator*.

To divide a fraction by a whole number; multiply the *denominator* by that number, and retain the *numerator*. Or in other words, if the whole number be treated as a fraction, invert this fraction, and proceed as in multiplication.

We have already shewn (8), that any whole number may be expressed as a fraction, by making the denominator unity; as $\frac{5}{1}$ is 5. Now to multiply the fraction $\frac{3}{20}$ by 5, $\frac{3}{20} \times \frac{5}{1} = \frac{15}{20}$. The unit in both the two fractions $\frac{3}{20}$ and $\frac{15}{20}$ is divided into 20 parts; and as of course 3 of such parts are taken in the first instance, and 15 in the second, and as 3 times 5 are 15, it is clear that 5 times as many parts are taken in the second instance as the first, and therefore the fraction is multiplied by 5.

The converse of this is shewn in the division of fractions: To divide a fraction by any whole number; *multiply* the *denominator* by that number, and *retain* the same *numerator*. Thus $\frac{15}{20}$ divided by 5 is $\frac{15}{20} \div \frac{5}{1} = \frac{15}{100}$; or $\frac{15}{20} \times \frac{1}{5} = \frac{15}{100}$.

The unit in the first fraction is divided into 20 equal parts, but in the second it is divided into 100 equal parts, each being of course $\frac{1}{5}$ of the former, because $5 \times 20 = 100$; now as the same number, 15, of such equal parts is taken in both cases, and as each of the parts is respectively only $\frac{1}{5}$ of the other parts, it is clear the fraction must be divided by 5.

The learner is requested to peruse this part very attentively, till he understands it thoroughly; as the whole theory of fractions depends upon a clear notion of the calculations of *equal parts* or divisions of *one whole* thing or integer.

To give a familiar illustration: multiply $\frac{3}{20}$ of a pound by 5; $\frac{1}{20}$ of £1. is of

course a shilling, because 20 shillings make one pound; here £1. is the unit or integer, see (2); each fractional part is $\frac{1}{20}$, or a shilling; 3 of these multiplied by 5 make 15 shillings, or $\frac{15}{20}$ of £1. If we spoke in terms of shillings nothing could be simpler; $3 \times 5 = 15$, or, see (8), $\frac{3}{1} \times \frac{5}{1} = \frac{15}{1} = 15$; but as we speak in terms of £1., $\frac{3}{20} \times 5 = \frac{3}{20} \times \frac{5}{1} = \frac{15}{20}$.

The same course of reasoning will prove the method of division, and the reader is requested to work it out himself, as a right understanding of fractional arithmetic depends on this.

The expression "in the terms of" may also be familiarly illustrated thus: 6 pence is $\frac{1}{40}$ in terms of £1., and $\frac{1}{2}$ in terms of a shilling; 3 pence is $\frac{1}{4}$ in terms of a shilling, $\frac{1}{2}$ in terms of 6 pence, and $\frac{1}{80}$ in terms of a pound.

It follows, from what has been said, that division may be performed by multiplication, by inverting the fraction; thus, $\frac{15}{20} \div 5 = \frac{15}{20} \div \frac{5}{1} = \frac{15}{100}$, as has been shewn: but the same result is found $\frac{15}{20} \times \frac{1}{5} = \frac{15}{100}$. The idea being, that a fraction always represents the division of the numerator by the denominator. See (7.)

From what has been said, it will also be easy to understand the conversion of a compound fraction to a simple one. Thus, by the rule, $\frac{2}{5}$ of $\frac{15}{20} = \frac{2 \times 15}{5 \times 20} = \frac{30}{100}$. It was shewn above, that $\frac{1}{5}$ of $\frac{15}{20}$ was $\frac{15}{100}$; and it is clear that $\frac{2}{5}$, or twice that quantity, is $\frac{30}{100}$.

Thus $\frac{7}{8}$ of 5 is $\frac{7}{8}$ of $\frac{5}{1} = \frac{35}{8} = 4\frac{3}{8}$. See (26.)

And $\frac{7}{8}$ of $\frac{3}{4}$ is $\frac{7 \times 3}{8 \times 4} = \frac{21}{32}$.

And $\frac{5}{6}$ of $\frac{7}{8}$ of $\frac{9}{10} = \frac{315}{480}$.

As whole numbers must be converted into fractions, so mixed numbers must be converted into improper fractions before the rule can be applied; thus,

$\frac{2}{3}$ of $\frac{3}{4}$ of $9\frac{1}{10}$ is equal to $\frac{6}{12}$ of $\frac{91}{10} = \frac{546}{120}$.

(28.) To convert a fraction into another of *greater* terms:

Multiply both the numerator and denominator by the term given.

Thus, $\frac{1}{4}$ in terms of double amount, is $\frac{2}{8}$, and of treble amount, $\frac{3}{12}$; $\frac{9}{10}$ in terms 6 times greater, is $\frac{54}{60}$; 8 times greater, $\frac{72}{80}$. See (11.)

(29.) To convert a fraction into another of *lower* terms:

If the numerator and denominator can each be divided by any number without a remainder, such number is called a "common measure." A "measure" has

already been defined (22). A "common measure" is that which may be applied to two or more numbers.

Find any common measure, divide both numerator and denominator by it, and the fraction is then reduced to *lower* terms.

Thus, in the fraction $\frac{48}{64}$, the numerator and denominator may both be divided by 8, which is therefore a common measure of them, and $(\frac{48}{64}) \div 8 = \frac{6}{8}$. This, again, may be divided by 2, and $(\frac{6}{8}) \div 2 = \frac{3}{4}$.

(30.) The *greatest* common measure of two numbers, is the greatest number that will divide them both without a remainder, and is found thus:

Divide the greater by the less; then divide the first divisor by the remainder, which forms a fresh divisor; then that fresh divisor by the last remainder, and so on, till nothing is left; the last divisor is the greatest common measure.

If only one be left as a remainder, the two numbers have no common measure, and are said to be prime the one to the other.

Thus, what is the greatest common measure of 189 and 1188?

```
189) 1188 (6
     1134
     ----
       54) 189 (3
           162
           ---
            27) 54 (2
                54
                --
```

Then is 27 the *greatest* common measure of these two sums.

Of course 9 or 3 would be *a* common measure of these sums, but 27 is the *greatest* common measure.

This rule is all that is usually necessary for fractional arithmetic, but it may not be amiss to give an example where three numbers are in question.

The rule is, find the greatest common measure between two of such numbers, and then the greatest common measure between the remainders.

Thus, what is the greatest common measure of 56, 512, and 768?

```
512) 768 (1
     512
     ---
     256) 512 (2
          ---
```

Therefore 256 is the greatest common measure between 512 and 768.

Then, what is the greatest common measure between 56 and 512?

$$\begin{array}{r l} 56)\ 512\ (9 & \\ 504 & \\ \hline 8)\ 56\ (7 & \\ 56 & \\ \hline \end{array}$$

Therefore 8 is the greatest common measure between 56, 512, and 768.

On this operation depends the very important rule in fractions, viz.:

(31.) To convert a fraction into another of equal value, but expressed in the lowest terms. Here the word "reduction" may be properly applied, and the rule may stand as in ordinary books, "to reduce a fraction to its lowest terms."

Rule: Find the greatest common measure between the numerator and denominator (as if they were two independent sums); divide them both by such common measure, and the two quotients will form respectively a new numerator and new denominator, and you will have a fraction converted into a new one of equivalent value with the former one, but in the lowest terms.

To make this branch of our subject more clear, the student will easily see that the fraction $\frac{24}{32}$ is equal in actual value to the fraction $\frac{12}{16}$, and also to the fraction $\frac{6}{8}$, because each fraction shews a similar proportional quantity, taken out of a whole number. Now, $\frac{6}{8}$ is equal also to $\frac{3}{4}$; but it is impossible to express $\frac{3}{4}$ in any lower terms, because the two essential parts of the fraction, the numerator and denominator, cannot be divided by the same sum without remainder. Now we have before shewn (11), that to form one fraction equivalent in value to another, both the numerator and denominator must be divided by the same sum; but as the numbers 3 and 4 cannot be divided by any sum (except unity) without a remainder, it is clear this fraction, and indeed every fraction that cannot be divided by any greater number than unity (or 1), is already in its lowest terms.

Ex.: To reduce $\frac{139}{1188}$ to its lowest terms.

Now we have already shewn (30), that 27 is the greatest common measure of

these two sums; both the numerator and denominator are to be divided by it. Thus,

$$\begin{array}{lll} 27)\ 189\ (7 & \quad\text{and}\quad & 27)\ 1188\ (44 \\ \ 189 & & \ 108 \\ \hline & & \ \ 108 \\ & & \ \ 108 \\ \hline \end{array}$$

The fraction in its lowest terms, therefore, is $\frac{7}{44}$. The student will see that, though 44 may be divided by several numbers, 11, 4, and 2; yet the number 7 cannot be divided by either of these.

Again, to reduce $\frac{512}{768}$ to its lowest terms. We have shewn above (30), that the greatest common measure of these two sums is 256; and

$$\begin{array}{lll} 256)\ 512\ (2 & \quad\text{and}\quad & 256)\ 768\ (3 \\ \ 512 & & \ 768 \\ \hline \end{array}$$

Therefore this formidable looking fraction is, after all, nothing but $\frac{2}{3}$.

Now the worth of this rule of conversion becomes developed by degrees.

(32.) To convert fractions into others having *one common denominator.*

First. If there be any compound fractions in the question, convert them into simple fractions, see (27); and if there be any mixed numbers, convert them into improper fractions, see (25); then proceed thus:

Multiply each numerator by all the denominators in the question successively, *except its own*, and put down their product as a new numerator; having done this by all the numerators, and having thus found as many new numerators as there were old ones, multiply all the denominators together for a common denominator, that is, a denominator which is to be affixed to all.

Thus: Convert $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{6}$, to a common denominator.

Now the common denominator will be, as last shewn, $2 \times 4 \times 6 = 48$.

The first new numerator will be, $1 \times 4 \times 6 = 24$.

The second, $3 \times 2 \times 6 = 36$.

The third, $5 \times 2 \times 4 = 40$.

The fractions then will be $\frac{24}{48}$, $\frac{36}{48}$, and $\frac{40}{48}$; and the student will readily perceive, by reference to what has before been explained, that the fractions are respectively of the same value.

Thus $\frac{24}{48} = \frac{1}{2}$; 24 being the greatest common measure.

$\frac{36}{48} = \frac{3}{4}$; 12 being the greatest common measure.

$\frac{40}{48} = \frac{5}{6}$; 8 being the greatest common measure.

Again, to reduce $\frac{3}{4}$, $\frac{1}{2}$ of $\frac{2}{3}$, and $3\frac{1}{3}$, to a common denominator: now $\frac{1}{2}$ of $\frac{2}{3} = \frac{2}{6}$, see (27), and $3\frac{1}{3} = \frac{10}{3}$, see (25). The fractions will therefore stand $\frac{3}{4}$, $\frac{2}{6}$, $\frac{10}{3}$. The common denominator as shewn above will be $4 \times 6 \times 3 = 72$, and

The first numerator $3 \times 6 \times 3 = 54$;

The second $2 \times 4 \times 3 = 24$;

The third $10 \times 4 \times 6 = 240$; and the three fractions will be $\frac{54}{72}$, $\frac{24}{72}$, and $\frac{240}{72}$.

(33.) From these rules it is clear that a simple rule of proportion may be found between two fractions, by reducing them to common denominators.

Thus $\frac{24}{48}$ is to $\frac{36}{48}$ as 24 is to 36; for by simple proportion $\frac{24}{48} : \frac{36}{48} :: \frac{24}{1} : \frac{36}{1}$. The integer being divided by the same number, and the parts being all equal, they must bear an equal ratio to each other.

(34.) To convert a fraction of a given denomination into integers equal in value, but in terms of a lesser denomination.

By this rule fractions of pounds may be converted into shillings, and (subsequently indeed) into pence; fractions of feet into inches; fractions of days into hours, minutes, seconds, and so on.

Rule. Multiply the fraction by the *number* of integers of the *lesser* denomination contained in *one* integer of the higher. The product is the value required.

Thus, what is the value of $\frac{5}{9}$ of a pound? Now £1. is equal to 20 shillings, and £1. is the greater integer, and one shilling the less.

Now it is clear that $\frac{5}{9}$ of £1. is of the same value as $\frac{5}{9}$ of 20 shillings, or $\frac{5}{9}$ of $\frac{20}{1}$ shillings, see (8), and $\frac{5}{9} \times \frac{20}{1} = \frac{100}{9}$; or, see (26), $11\frac{1}{9}$ in terms of shillings.

Next, what is the value of $\frac{1}{9}$ of a shilling? The lesser denomination to a shilling is a penny, and 12 pence make a shilling. Now, by the rule, multiply $\frac{1}{9}$ by 12, or $\frac{1}{9} \times \frac{12}{1} = \frac{12}{9}$; or, see (26), $1\frac{3}{9}$, or one penny and $\frac{3}{9}$.

Now reduce this fraction to terms of the next lowest denomination; this is a farthing, and as there are four farthings in a penny we proceed as above, and $\frac{3}{9} \times \frac{4}{1} = \frac{12}{9}$, or, see (26), $1\frac{3}{9}$; and therefore the fraction $\frac{5}{9}$ of £1. may be converted into 11 shillings, 1 penny, 1 farthing, and $\frac{3}{9}$ of a farthing.

Convert $\frac{4}{5}$ of a chain to terms of feet and inches: a chain is 66 feet; then

$\frac{4}{5} \times \frac{66}{1} = \frac{264}{5}$; or, (26), $52\frac{4}{5}$. There are 12 inches in a foot, and $\frac{4}{5}$ of a foot is the same as $\frac{4}{5}$ of 12 inches; or $\frac{4}{5} \times \frac{12}{1} = \frac{48}{5} = 9\frac{3}{5}$. To reduce this to eighths of an inch, $\frac{3}{5} \times \frac{8}{1} = \frac{24}{5} = 4\frac{4}{5}$. Therefore $\frac{4}{5}$ of a chain is 52 feet, 9 inches, 4 eighths, and $\frac{4}{5}$ of an eighth.

Or at length, what is the value of $\frac{9}{15}$ of a cwt.?

```
         9
         4 quarters in cwt.
      ----
  15) 36 (2 qrs.
      30
      ----
       6
      28 lbs. in a quarter.
     -----
  15) 168 (11 lbs.
      15
      ---
       18
       15
      ---
        3
       16 oz. in a lb.
      ----
  15) 48 (3 oz.
      45
      ----
Rem.   3-15 parts of oz.
```

Then $\frac{9}{15}$ of a cwt. = 2 qrs. 11 lbs. 3 oz. $\frac{3}{15}$.

It is not necessary to go through all the intermediate values, but we may find the value of a fraction in terms of any lower denomination by multiplying by the total number of integers contained in the one of higher amount: thus, what is the value of $\frac{6}{7}$ of £1. in terms of a farthing? Now $20 \times 12 \times 4 = 960$, the number of farthings in £1., then

```
      6
    960
   ----
7) 5760
   ----
    822. 6.
```

Therefore $\frac{6}{7}$ of £1. = $822\frac{6}{7}$ farthings.

(35.) To convert any quantity into a fraction of any denomination:

[*Case* 1.] If the given quantity be a simple sum, make it the numerator, and take the number of integers of its denomination which make up one integer of the new or proposed denomination; make this the new denominator, and the fraction is obtained.

Thus, what fraction of a pound is 11 shillings?

First, the new numerator will be the number of integers, or 11.

The new denominator will be the number of times the integer named, or shillings, is contained in a pound, or 20.

Therefore the new fraction will be $\frac{11}{20}$.

What fraction of a load of timber is 10 cubic feet?

The numerator as above is 10; 50 cubic feet make a load; therefore the new denominator will be 50, and the fraction will be $\frac{10}{50}$, or $\frac{1}{5}$.

[*Case* 2.] If more whole numbers or integers than one be given. Reduce the whole to the lowest number named, and make this the numerator, and find the number of parts the lowest integer contains in the denomination required, and make this the denominator.

Thus, what fraction of a pound is 9s. $7\frac{1}{4}$d.? Bring the whole sum into farthings, and find how many farthings, or *lowest* integers, are contained in £1., or the *highest* integer: thus,

9s. $7\frac{1}{4}$d.	20s. in £1.
12	12
115	240 pence in £1
4	4
461	960 farthings in £1.

Therefore the required fraction is $\frac{461}{960}$.

What fraction of 1 cwt. of lead is 1 qr. 14 lbs.?

Now 1 cwt. = 112 lbs.

And 1 qr. = 28 lbs. Then 28 lbs. + 14 = 42lbs.

And the fraction is $\frac{42}{112}$.

[*Case.* 3.] When a common denominator can be found between the two quantities, they may be converted, (32), and the fraction is obtained.

Thus, as above, 1 qr. is $\frac{1}{4}$ of 1 cwt., and 14 lbs. $\frac{1}{2}$ of $\frac{1}{4}$.

$$\text{Then } \tfrac{1}{2} \text{ of } \tfrac{1}{4}\ (27) = \tfrac{1}{8};$$
$$\text{And } \tfrac{1}{4}\quad (28) = \tfrac{2}{8}.$$

Then the fraction will be $\frac{3}{8}$ of 1 cwt.

Any common denominator would *reduce* the fraction, but if the *greatest* be taken, the fraction is then in its *lowest* terms.

The above case may be proved thus: the greatest common measure between $\frac{42}{112}$ is—

```
42) 112 (2
     84
    ------
     28) 42 (1
         28
        ------
         14) 28 (2
            ------
```

And therefore 14, (30), is the greatest common measure. Now $42 \div 14 = 3$, and $112 \div 14 = 8$; and therefore the fraction, as above stated, is $\frac{3}{8}$.

What fraction of a guinea is 3s. 6d.?

The greatest common denominator between them is sixpence. (They both contain pence and farthings, which are *common* denominators, but the *greatest* common denominator is sixpence.)

Then as 3s. 6d. = 7 sixpences;
And as a guinea = 42 sixpences;

The fraction is $\frac{7}{42}$; and the common measure is 7, and the fraction, reduced to its lowest terms, (31), is $\frac{1}{6}$.

(36.) To convert a fraction into another fraction of any denomination.

Take an integer of the proposed denomination, and find what fraction that is of an integer of the given fraction, then find its result as a compound fraction, as directed in (27).

Thus, what fraction of a pound is $\frac{5}{6}$ of a shilling? Now 20s. = £1., and 1s. = $\frac{1}{20}$ of £1. Then the fraction is $\frac{5}{6}$ of $\frac{1}{20}$ of £1., or, (27), $\frac{5}{120}$ of £1.

What fraction of a chain is three quarters of a yard?

Now 1 yard is $\frac{1}{22}$ of a chain, and the fraction will be $\frac{3}{4}$ of $\frac{1}{22}$, or $\frac{3}{88}$ of a chain.

What fraction of a day's work is $\frac{3}{5}$ of an hour?

The working day is 10 hours; then the fraction is $\frac{3}{5}$ of $\frac{1}{10}$, or $\frac{3}{50}$.

ADDITION OF FRACTIONS.

(37.) [*Case* 1.] If fractions have the same or a common denominator, add the numerators together, and retain the old denominator.

Thus, $\frac{3}{10} + \frac{4}{10} = \frac{7}{10}$.

This is clear, because each represents a certain number of integers of the same value; thus $\frac{1}{4} + \frac{2}{4}$ of a penny, is $\frac{3}{4}$; just as 1 farthing + 2 farthings = 3 farthings.

Again, $\frac{1}{8} + \frac{2}{8} + \frac{3}{8} = \frac{6}{8}$, (as may be seen by inspecting any common 2 foot rule.)

[*Case* 2.] If the fractions have not a common denominator, reduce them to a common denominator, and then proceed as in Case 1. Thus, what is the sum of $\frac{3}{4}, \frac{5}{6}, \frac{7}{8}$? Then (32) the fractions converted into a common denominator are, $\frac{144}{192}, \frac{160}{192}, \frac{168}{192}$, and therefore the sum of these is $\frac{472}{192}$, or (26) $2\frac{88}{192}$, or (31) $2\frac{44}{96} = 2\frac{11}{24}$.

[*Case* 3.] If mixed numbers or compound fractions are to be added together, reduce them to improper fractions, and then proceed as before.

Thus, add together $2\frac{1}{3}, 3\frac{1}{4}, 5\frac{1}{6}$.

Then (25) the fractions are $\frac{7}{3}, \frac{13}{4}, \frac{31}{6}$.

Reduce these to a common denominator (32).

The common denominator is	$3 \times 4 \times 6 = 72$.
The first numerator	$7 \times 4 \times 6 = 168$.
The second	$13 \times 3 \times 6 = 234$.
The third	$31 \times 3 \times 4 = 372$.

The fractions will be $\frac{168}{72} + \frac{234}{72} + \frac{372}{72} = \frac{774}{72}$; and reducing this to the lowest terms, find the greatest common measure (30), = 18, and then dividing by it, (31), we obtain the fraction $\frac{43}{4}$, or (26) $10\frac{3}{4}$.

SUBTRACTION OF FRACTIONS.

(38.) To subtract one fraction from another, or, more properly, to find the difference between two fractions, proceed as follows:

[*Case* 1.] If both fractions have a common denominator, take the difference between the numerators, and retain the denominator.

Thus, what is the difference between $\frac{3}{8}$ and $\frac{7}{8}$ of an inch?

Now as the unit is divided into 8 equal parts, and as we suppose three of those parts or eighths are to be taken from seven of such parts, it is clear the remainder is four, or $\frac{4}{8}$.

[*Case* 2.] If they have no common denominator, convert them into fractions having a common denominator, and deduct as above.

Thus, take $\frac{6}{7}$ from $\frac{1}{5}$.

Now it must be borne in mind that this system of subtraction is a system of differences; $\frac{6}{7}$ being greater than $\frac{1}{5}$, the former cannot be taken from the latter in the ordinary sense of the words; but if we convert the fractions to others of a common denominator, (32), we can find their difference:

$$7 \times 5 = 35 \text{ for the new denominator;}$$

$$\left.\begin{array}{r}\text{And } 6 \times 5 = 30 \\ \text{And } 1 \times 7 = 7\end{array}\right\} \text{for the new numerators.}$$

The fractions are therefore $\frac{30}{35}$ and $\frac{7}{35}$, and the difference $\frac{30}{35} - \frac{7}{35} = \frac{23}{35}$.

[*Case* 3.] Where one or both fractions are mixed numbers, or compound fractions, convert them into improper fractions, and proceed as before.

This is the converse of the rule for addition, and has been so amply explained that we think no example necessary.

MULTIPLICATION.

The reader is requested to reperuse (27), where this branch of our subject has been in part anticipated, and to give his earnest attention to the following paragraphs, as they are of the greatest importance to understanding this branch of mathematics.

(39.) To multiply one fraction by another, multiply the numerators for a new numerator, and the denominators for a new denominator.

Thus $\frac{3}{4} \times \frac{5}{6} = \frac{15}{24}$.

And $\frac{10}{32} \times \frac{8}{9} = \frac{80}{288}$.

To avoid the confusion sometimes caused in the mind of the young student, who expects that multiplication of two quantities must necessarily give an increased product, and who finds the results invariably less; as $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$; it must be borne in mind that in reality to multiply one fraction by another is to *take such parts of one fraction as the other expresses*; thus $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ is (in common words) the half of a half, which is of course a quarter. It is in reality not a quantity multiplied by another, as half a shilling is sixpence, and 6 times 6 pence = 36 pence; but having a half, as 6 pence, we take the half of that again, or 3d., which of course is $\frac{1}{4}$ of a shilling.

Mixed numbers must be converted into improper fractions, and compound fractions into simple fractions.

Thus, multiply $3\frac{1}{4}$ by $9\frac{3}{8}$.

Then (25) we have $\frac{13}{4} \times \frac{75}{8} = \frac{975}{32}$.

Multiply $\frac{2}{3}$ of $\frac{5}{6}$ by $\frac{9}{10}$ of $\frac{7}{8}$.

Then (27) $\frac{2}{3}$ of $\frac{5}{6} = \frac{10}{18}$, and $\frac{9}{10}$ of $\frac{7}{8} = \frac{63}{80}$, and $\frac{10}{18} \times \frac{63}{80} = \frac{630}{1440}$, the greatest common measure of which is 90, and the fraction $\frac{7}{16}$.

If it is required to multiply a fraction by a whole number, express such number fractionally, as has been shewn, (8), and proceed as above.

Multiply $\frac{7}{8}$ by 20.

This is $\frac{7}{8} \times \frac{20}{1} = \frac{140}{8}$.

Multiply $\frac{3}{63}$ by 9.

$\frac{3}{63} \times \frac{9}{1} = \frac{27}{63}$.

It will be seen that 9 is a common measure of this fraction, and that it may be expressed as $\frac{3}{7}$. As $63 \div 9 = 7$, it may be seen that a fraction may be multiplied by another by dividing the denominator by that sum, and retaining the numerator, if such division can be made without remainder.

In all cases of fractional arithmetic where whole numbers are used, we should advise the student immediately to express them as fractions, (8); it will save much trouble, and avoid errors.

DIVISION.

(40.) To divide one fraction by another, invert the numerator and denominator of the division, and multiply them together, as (39.)

Thus, divide $\frac{7}{8}$ by $\frac{3}{10}$.

$\frac{7}{8} \times \frac{10}{3} = \frac{70}{24}$, or $2\frac{22}{24}$.

Divide $\frac{1}{2}$ by $\frac{1}{2}$. Then $\frac{1}{2} \times \frac{2}{1} = \frac{2}{2} = \frac{1}{1} = 1$.

It was shewn (39) that multiplication is in reality the *taking such part of one fraction as the other expresses;* to multiply $\frac{3}{4}$ by $\frac{5}{6}$ is to take three quarters of five sixths. Division is the reverse of this. To divide one fraction by another is to find *how often one is contained in the other;* thus it is clear that $\frac{1}{2}$ is contained once in $\frac{1}{2}$. As above, convert $\frac{7}{8}$ and $\frac{3}{10}$ into fractions with a common denominator (32), they will be $\frac{70}{80}$ and $\frac{24}{80}$, or (33) $\frac{70}{1}$ and $\frac{24}{1}$, or (8) $70 \div 24$ or (7) $\frac{70}{24}$.

Mixed numbers must in all cases be converted into improper fractions, and compound fractions into simple ones.

To divide a fraction by a whole number, express the number fractionally, and proceed as before.

Divide $\frac{1}{25}$ by 5.

5 is $\frac{5}{1}$. Then $\frac{1}{25} \times \frac{1}{5} = \frac{1}{125}$.

QUESTIONS FOR PRACTICE.

[24.] Convert 12 into a fraction whose denominator is 144.

[25.] Convert 397 into a fraction whose denominator is 41, and 172 into a fraction whose denominator is 14001.

[26.] Convert $2\frac{33}{51}$, $9\frac{76}{133}$, $3743\frac{119}{144}$ into improper fractions.

[27.] A carpenter has worked 4 single days at a job, and 3 single quarters; express as an improper fraction how many quarters he has worked.

[28.] Convert $\frac{381}{15}$, $\frac{7973}{251}$, $\frac{8641}{32}$, $\frac{967}{842}$, $\frac{999}{991}$, each respectively to mixed numbers.

[29.] Convert $\frac{9}{10}$ of $\frac{10}{11}$ to a simple fraction.

[30.] The same with $\frac{397}{1000}$ of $\frac{39}{50}$; $\frac{99}{101}$ of $\frac{32}{102}$; $\frac{50}{66}$ of $\frac{1}{22}$.

[31.] Convert $\frac{22}{33}$ into fractions of 3, 4, 5, 6, 7, and 8 times its present terms.

[32.] I hold five sixths of the chances at a raffle; the amount is doubled: express the fractional part of the interest I have in double the terms.

[33.] Convert $\frac{100}{1000}$, $\frac{46}{58}$, $\frac{1236}{22}$, into fractions of half their terms.

[34.] Convert $\frac{33}{423}$, $\frac{66}{198}$, $\frac{90}{273}$, into fractions of one third lower terms.

[35.] 96 and 144 may both be divided by 12. What is the fraction $\frac{96}{144}$ converted into another of 12th lower terms?

[36.] What is $\frac{1}{3}$ of $\frac{1}{4}$ of $\frac{1}{5}$ of $\frac{1}{6}$ of $\frac{1}{7}$ of $\frac{1}{8}$?

[37.] What is $\frac{1}{2}$ of $\frac{2}{3}$ of $\frac{3}{4}$ of $\frac{4}{5}$ of $\frac{5}{6}$ of $\frac{6}{7}$ of $\frac{7}{8}$?

[38.] What is the greatest common measure of 332 and 2656? of 7956 and 9168? of 99 and 1881?

[39.] What is the greatest common measure of 51, 136, and 170? of 764, 1146, and 2292?

[40.] What is the greatest common measure of 1332, 1665, 1998, and 2331? of 88, 528, 6336, and 76032?

[41.] Convert $\frac{33}{297}$, $\frac{1371}{10968}$, $\frac{12108}{1012}$, $\frac{11111}{99999}$, to their lowest terms.

[42.] Two places are 15 degrees, or $\frac{15}{360}$ of the earth's circumference, apart. State this distance in its lowest fractional terms.

[43.] There are 120 shares in a mining company. A. has bought 25. What fractional part of the concern does he possess, expressed at its lowest terms? To possess the fourth part of the shares qualifies to be chairman: how many more must he buy for this purpose?

[44.] Convert $\frac{1}{9}$, $\frac{1}{10}$, $\frac{1}{11}$, $\frac{1}{12}$ to a common denominator.

[45.] Convert $\frac{3}{4}$, $\frac{19}{20}$, $7\frac{1}{3}$, $\frac{122}{360}$ to a common denominator.

[46.] Shew how $\frac{76}{98}$ and $\frac{132}{144}$ may be stated, so as to shew a simple method of proportion between them.

[47.] What is the value of $\frac{3}{11}$ of a pound?

[48.] What is the value of $\frac{33}{50}$ of a chain?

[49.] What fraction will express the third of a rod of brickwork in terms of cubic feet?

[50.] At the close of a job a builder gives a lot of old stuff to be divided

among 15 carpenters; it measures a load and a quarter cube; two of them buy up the shares of the rest; thus, one buys 7 shares, the other the remainder, except of one person, who will not sell his share. What fractional parts has each got, and how may they be expressed in terms of a foot cube?

[51.] What fraction of £1. is $2\frac{1}{2}$d.?

[52.] I give 35 carpenters a pot of beer each, to 20 labourers a pint each, and to six boys half a pint each. What fractional part is this of a butt of beer?

[53.] What fractional part is a three-out glass of a gallon of rum?

[54.] I agree to prepare and fix some rough fence to a railway at per mile, and find during the first week that 532 ft. 9 in. has been done. What fraction is that of the mile?

[55.] What fraction of a ton is one hundredweight, one quarter, and one stone horseman's weight?

[56.] What fraction of a mile is a chain and a fifth?

[57.] Add together $\frac{1}{2}$, $\frac{2}{3}$, $\frac{4}{5}$, $\frac{5}{6}$, and $\frac{7}{8}$.

[58.] Add together $\frac{9}{10}$, $\frac{7}{8}$, $\frac{5}{6}$, $\frac{3}{4}$, $\frac{1}{2}$.

[59.] Add together $1\frac{1}{2}$, $2\frac{3}{4}$, $3\frac{5}{6}$, $4\frac{7}{8}$.

[60.] Add together $\frac{132}{264}$, $3\frac{19}{20}$, $\frac{131}{51}$.

[61.] Subtract $\frac{21378}{197634}$ from $\frac{3321}{66732}$.

[62.] What is the difference between ten and a ninth, and nine and a tenth?

[63.] What is the difference between $\frac{1}{9}$ and $\frac{1}{10}$?

[64.] The Excise allow one tenth for waste off the duty on bricks, and

charge on the less sum. I am charged for a million and a quarter of bricks, how many have actually been made?

[65.] What is the difference between a third *of* a third, and a third *and* a third?

[66.] Multiply half an inch by one quarter of a yard, all expressed in terms of a foot.

[67.] Multiply $\frac{1}{10}$ of a chain by $\frac{1}{100}$ of a chain, and state the product in terms of a foot.

[68.] Multiply a half, by a half of a half.

[69.] Divide $\frac{1}{3}$ by $\frac{1}{33}$.

[70.] Divide a fifth, by a fifth of a fifth.

[71.] Divide $\frac{84}{96}$ by $\frac{216}{504}$ in the shortest manner, and express the same in the lowest terms.

[72.] What is the third and half the third of five-pence halfpenny?

[73.] What are the two-tenths and half a tenth of a shilling?

[74.] At the Saw Mills they cut 16 veneers out of an inch; the saw curf is $\frac{1}{3}$ less than the veneer; how thick is the veneer in terms of an inch, supposing the flitches of mahogany to be wrought 4 inches thick?

[75.] I send a piece of rosewood 8 inches thick to be cut as above; what proportion is each veneer of the whole log, supposing the outside flitches to have been cut off, and the log left parallel and square?

DECIMAL FRACTIONS.

It has been seen that however valuable fractional calculations may be, there is great labour and trouble in all cases of addition and subtraction where it is necessary to bring the fractions to a common denominator; particularly where many fractions are in the operation. To facilitate these calculations, the system of Decimals was invented; a system of immense value, affording facilities in calculation few would believe who do not understand them; and of such daily

increasing use—a use probably to extend to our coinage, and weights, and measures—that we trust our readers will give their most earnest attention to this branch of practical mathematics.

(41) Decimal fractions are those whose denominators are always 10, or some product of 10 multiplied into itself, or (16) power of 10, as 10, 100, 1000, 10,000, &c. &c.

(42.) The place where the figure 1 in the denominator would be, if fractionally expressed, is denoted by a point (.), usually called the decimal point ; thus the following fractions are expressed decimally as under,

$$\frac{2}{10}, \ \frac{99}{100}, \ \frac{472}{1000}, \ \frac{3573}{10000},$$
$$\text{or } .2, \ .99, \ .472, \ .3573.$$

This saves the trouble of drawing a line, and writing the fraction in full.

So also $14\frac{4}{10} = \frac{144}{10} = 14.4.$ $137\frac{45}{100} = \frac{13745}{100} = 137.45.$

(43.) Should there be more cyphers in the denominator than there are figures in the numerator, then the decimal is expressed by adding cyphers to the *left* of the numerators to make up the surplus, the point (.) being always supposed to represent the figure 1. Thus,

$$\frac{7}{100} = .07, \quad \frac{53}{10000} = .0053, \quad \frac{1007}{100000} = .01007.$$

(44.) The figures to the left of the decimal point (.) are integers, and are always treated as such, without regard to those which follow; those to the right are decimal fractions of such integers in proportions as described above. Thus $19.7 = 19\frac{7}{10}$, $21\frac{33}{100} = 21.33$, $44\frac{7}{100} = 44.07$, $3\frac{17}{100000} = 3.00017$.

(45.) The value of every figure in a decimal expression becomes less by one-tenth as it is placed to the right ; every figure in a decimal expression is ten times greater than the one following, or to the right of it ; and ten times less than the preceding one to the left of it.

Thus .5, .05, .005, .0005 are respectively

$$\frac{5}{10}, \ \frac{5}{100}, \ \frac{5}{1000}, \text{ and } \frac{5}{10000}.$$

The decimal .9763 is $\frac{9}{10} + \frac{7}{100} + \frac{6}{1000} + \frac{3}{10000}$.

All these are divisions of the integer or unit, or the first figure to the left of the decimal point (.)

(46.) If we add cyphers to the right of a decimal, it does not affect its value ;

thus .7, .70, .700, are all of equal value, because they represent the several fractions $\frac{7}{10}$, $\frac{70}{100}$, $\frac{700}{1000}$, all of which fractions are equal in value (11).

So if it be necessary to express decimals as fractions, it is clear they may be converted into those of a common denominator, by adding cyphers (to the right of course), both to the numerator and denominator.

ADDITION OF DECIMALS.

(47.) To add decimals together, place the figures so that those of the same denomination may stand under each other, and the points of course will be always in the same line ; add them together as in ordinary arithmetic, keep the decimal point always in the same relative place, and if any numbers are carried beyond the decimal point to the left in the course of addition, they then become integers, and are treated as in common addition.

Add together .9, .17, .023, .7302.

Now these, as above stated, if considered as fractions reduced to a common denominator, would be $\frac{9000}{10000} + \frac{1700}{10000} + \frac{0230}{10000} + \frac{7302}{10000}$, and the addition would be as they are all represented by one common denominator.

$$.9000 + .1700 + .0230 + .7302 = 1.8232.$$

Or without the cyphers to the right hand, which, as has been shewn above, are superfluous,

$$.9 + .17 + .023 + .7302 = 1.8232.$$

Perhaps it may be well here to remark, that a species of numeration analogous to that of integers is clearly to be derived from what has been said : thus, the first figure in any sum is the unit; this place *decimally* is taken by the point (.); the first place to the left of the unit represents the tens, the first to the right of the decimal point the tenths; the second to the left hundreds, the second to the right hundredths, &c. &c. ; the value of this system is that the whole number and the decimals may be so readily added or subtracted, without conversion of the integral part to improper fractions, or without assuming the fractional form, *id est*, the form of numerator and denominator.

SUBTRACTION.

(48.) Subtraction is performed in exactly an analogous manner: thus, place

the figures under each other, being very careful always to keep the decimal points under each other, and proceed as in common arithmetic.

Thus, from 7.856 take 3.947.

$$\begin{array}{r} 7.856 \\ 3.947 \\ \hline 3.909 \end{array}$$

If there be more figures in the first than in the second sum, supply the deficiency either by adding cyphers to the right, or suppose them to be added; they then, as above stated, (45) and (46), become converted to a common denominator.

Thus from 71.5 subtract 5.0732. Fractionally expressed these sums are $\frac{715}{10}$ and $\frac{50732}{10000}$, and converted to a common denominator become $\frac{715000}{10000}$ and $\frac{50732}{10000}$, and of course

$$\begin{array}{r} 71.5000 \\ 5.0732 \\ \hline 66.4268 \end{array}$$

Or without the cyphers $71.5 - 5.0732 = 66.4268$.

Great care must be taken, as in Addition, to keep the decimal points under each other. Thus from 3402.005 take .006679.

$$\begin{array}{r} \text{Then } 3402.005 \\ .006679 \\ \hline 3401.998321 \end{array}$$

MULTIPLICATION.

(49.) Multiplication of Decimals is performed exactly as that of integers; afterwards count how many decimal places there are in the multiplier and multiplicand both together, and cut off the same number of figures from the end of the product by a point; those to the left of the point will be the integers, and those to the right decimals.

Thus, multiply 71.5 by 6.3.

$$\begin{array}{r} 715 \\ 63 \\ \hline 2145 \\ 4290 \\ \hline 45045 \end{array}$$

Now as there are two decimals in the multiplier and multiplicand, one in each, we must point off two from the end of the product, which will be 450.45. The reason of this is, that if converted into fractions they would be, (42), $\frac{715}{10} \times \frac{63}{10}$, and of course $= \frac{45045}{100}$; this converted into a mixed number, (26), is $450 \frac{45}{100}$; and $\frac{45}{100}$ (42) $= .45$. Therefore the product is 450.45.

(50.) If there be not enough figures in the product to make up the number of decimals in the multiplier and multiplicand taken together, there must be as many cyphers added to the *left* of the product, so that the whole number of decimal places may be made up. See (45) and (46).

Thus multiply .256 by .107. Then: $256 \times 107 = 27392$.

Now here are only five figures altogether, whereas there are six in the multiplier and multiplicand; I must therefore add one cypher to the left, and place the decimal point before it, and the product will be .027392.

DIVISION.

(51.) Division of Decimals is performed exactly as in integers, and the decimal places in the quotient are found by pointing off as many figures from the end of the quotient, as the number of decimals in the dividend exceeds the number of decimals in the divisor.

Thus, divide 450.45 by 71.5.

```
715) 45045 (63
     4290
     ----
      2145
      2145
      ----
```

Now as there are two places of decimals in the dividend, and only one in the divisor, I point off the *difference*, namely, one figure, and the quotient is 6.3. The reason of this will be seen by referring to (49). If $71.5 \times 6.3 = 450.45$, it is clear $450.45 \div 71.5 = 6.3$. Now we have seen that the number of decimals in the product was found by adding the number of those in the multiplier and multiplicand together, namely 2; and therefore it is clear, that in the second operation (that of division) we must take the difference, namely 1.

(52.) In the same way, if there are not figures enough to make the difference, cyphers must be added to the left of the quotient till the number is complete.

Thus, divide .864 by 14.4.

```
144) 864 (6
     864
     ---
```

Now as there are three decimals in the dividend and only one in the divisor, I must have two decimals in the quotient, which will be .06. The reason is, that if expressed fractionally (42) they will be $\frac{864}{1000}$ and $\frac{144}{10}$; and (40), $\frac{864}{1000} \div \frac{144}{10}$

$= \frac{864}{1000} \times \frac{10}{144} = \frac{8640}{144000}$, and this reduced to its lowest terms (31) $= \frac{6}{100}$, which is expressed decimally (42) .06.

(53.) The dividend must contain at least as many decimal places as the divisor; if it does not, cyphers must be added to the *right* till there are enough.

Thus, divide 108 by .018.

Now $108 = 108.000$, (46), and $108.000 \div .018 = 6000$.

This may be proved by multiplication—thus, $.018 \times 6000 = 108.000$, or 108.

(54.) The same system must be pursued when there are remainders in the division.

Divide 4 by 62.5.

```
625) 4000 (64
     3750
     ----
      2500
      2500
      ----
```

Here are four decimals in the dividend, and only one in the divisor; the quotient must consist of three decimals, and is of course .064.

CONVERSION OF DECIMALS.

(55.) To convert a vulgar fraction to a decimal, divide the numerator by the denominator, adding cyphers as before if necessary, and observing the rules of the three preceding articles.

Convert $\frac{1}{4}$th to a decimal.

```
4) 1.00
   ----
     25 or .25.
```

Convert $\frac{3}{8}$ths to a decimal.

```
8) 3.000
   -----
     375 or .375.
```

Convert $\frac{4}{125}$ to a decimal. $4.000 \div 125 = 32$.

Now as there are three decimals in the dividend and none in the divisor, this will be .032.

The reason of this is apparent from the rules given for the conversion of fractions, (24, &c.), the decimal being a fraction whose denominator is 10, 100, 1000, &c. &c.

(56.) It often happens that fractions are not formed of numbers which are wholly composed of tenths, hundredths, &c.; in this case, on proceeding to division, we constantly find a remainder, and the division would go on for ever. Thus, $\frac{2}{3}$rds cannot be made a perfect decimal.

$$3\underline{)\,2.0000}$$
$$.6666 \text{ \&c. for ever.}$$

Thus $\frac{5}{6} = 6\underline{)\,5.0000}$
$.8333$ &c.

Thus $\frac{4}{33} = \frac{4.000}{33} = .121212$, &c.

Thus $\frac{2}{135} = \frac{2.0000}{135}$ &c. $= .0148148148$, &c.

These are called circulating or recurring decimals.

[57.] To convert a decimal into another of lower value, or of lower denomination.

Consider the decimal as a fraction whose denominator is 10, or 100, or 1000, &c. &c. &c., proceed as in (34, &c.)

Or, at length; multiply the quantity by the number of integers of its denomination contained in one of the inferior denominations, and (repeating this as often as necessary) the products are the successive decimals required.

Thus, what is the value of .1925 of £1?

Then	.1925	
	20	shillings in £1.
	3.8500	
	12	pence in a shilling.
	10.2000	
	4	
	.8000	or 3s. 10d. and $\frac{8}{10}$ of a farthing.

What is the value of .725 of a chain in terms of a foot?

.725	
66	feet in a chain.
4350	
4350	
47.850	
12	inches in a foot.
10.200.	Or 47 feet 10 inches $\frac{2}{10}$ths of an inch.

[58.] To convert a quantity into a decimal of a greater denomination.

Proceed as in the reverse of the last article, and on the principles laid down before in the conversion of fractions (24, &c.)

Or, more shortly. Divide the quantity by the number of integers of its own denomination contained in one of the greater denomination, the quotient is the decimal required. If there be any intermediate denomination, proceed in the same way as shewn in fractions, till you arrive at the proper denomination.

What decimal of a foot is 3 inches?

Now 12 inches make a foot.

$$12)\underline{3.00}$$

$.25.$ Suppose we consider the denomination as feet, then its value as feet must be $\frac{1}{12}$th its value as inches.

What decimal of a pound is 16s. $7\frac{1}{4}$d?

$$\begin{array}{rl} \text{Then,}\quad 4) & \underline{1.00} \\ 12) & \underline{7.25} \\ 20) & \underline{16.604166} \\ & 83020833 \end{array}$$

In effect, we find first what decimal of a penny a farthing is, then what decimal of a shilling seven pence is with the previous decimal attached to it, and so on till we arrive at the decimal of a pound.

We have now reached what may be considered the conclusion of the first branch of Practical Mathematics, that of Fractional and Decimal Arithmetic. There is, however, one branch closely connected with Decimal Arithmetic,—the subject of Involution and Evolution,—on which we wish to treat before giving any questions for practice. We again earnestly entreat the attention of our readers to this branch of our subject. It is easy to master with patience; and whoever wishes to march with the times, must make up his mind to the exertion, or he may be sure that that branch of the building business, the Carpenter's, will sink in the scale, instead of maintaining the respectable position it always has supported.

Division A.

PRACTICAL RULES ON DRAWING,

FOR THE

OPERATIVE BUILDER AND YOUNG STUDENT IN ARCHITECTURE.

CHAPTER I.

INTRODUCTORY.

Much of the art of Drawing and Painting—one of the most useful, as well as one of the most elegant, of acquirements—is to be attained by patient and well directed industry, without the aid of a master. In evidence of this may be adduced the fact that many ancient and modern painters, almost entirely self-taught, have arrived at the greatest eminence in their profession. Within the writer's recollection, many personal friends and acquaintance, men literally sprung from nothing, by an assiduous application of the little leisure afforded them from those pursuits on which depended their daily bread, have gradually raised themselves to the highest rank among their professional brethren. Five individuals, whose occupations were those of a groom, a bottle cleaner, a waiter, a tailor, and a plough boy—three of whom are now living, and all of whom were personally known to the writer—by dint of their talent and unflinching perseverance, placed themselves in the highest rank of artists, and became the courted guests of some of the first nobility and gentry of the country. The world too generally attributes the rise of such men to their *genius* alone, rather than to that persevering industry and courageous battling with difficulties, which in the long run must overcome every thing that opposes them; and though to assert that the talent or capacity of all men is equal would be absurd, yet it is generally admitted, that a moderate capacity,

backed by steady industry, is more successful than brilliant talents without perseverance. In the discourses on painting by Sir Joshua Reynolds, a work the perusal of which cannot be too strongly recommended to every student, occurs the following passage: "There is one precept in which I shall only be opposed by the vain, the ignorant, and the idle. I am not afraid that I shall repeat it too often;—you must not depend on your own GENIUS. If you have great talents, industry will improve them; if you have but moderate abilities, industry will supply their deficiency. Nothing is denied to well-directed labour, nothing is to be obtained without it. Not to enter into metaphysical discussions on the nature or essence of genius, I will venture to assert, that assiduity unabated by difficulty, and a disposition eagerly directed to the object of its pursuit, will produce effects similar to those which some call the result of natural powers." Experience has proved the truth and value of these observations; the young student must not, therefore, suffer himself to be discouraged by any want of success that may attend his first endeavours, neither let him be too much elated by injudicious praise. The acquirement of Drawing is too much looked upon as a mere accomplishment, and its usefulness undervalued; the knowledge of Painting is absolutely the acquisition of a new sense. In the writer's experience as a teacher, it has been lamentable to witness how many highly gifted young people have been debarred from learning this eminently useful art, by the folly and ignorance of their parents, whose constant cry has been: "It is of no use paying money for lessons for my son or daughter, for they have no taste." It would be as absurd to prevent a youth from studying the mathematics, from the fear he would never make a Newton, as it is to withhold him from the pursuit of drawing, because he may not, forsooth, be capable of becoming a Lawrence or a Turner. In the present day, such facilities are to be met with for the acquirement of every branch of knowledge, that ignorance can only be the consequence of idleness. Few individuals are so constituted but that, by proper direction and diligent application, they may, by their own exertion, obtain such a fund of information, as will fit them to pass through the world as useful and well-informed members of society. It is our task to furnish the means by which those totally unacquainted with drawing may, by careful application, teach themselves this art.

The art of Drawing is entirely an imitative one; for the finest works unquestionably are those the truest to their prototype—Nature. It is necessary, in the study of this,—as in the study of all other things to be well understood,—to begin at the beginning. A picture consists of various individual parts or objects,

so combined as to form an agreeable whole, whether portrait, landscape, or architecture ; and it is indispensable that the student understand and draw these separate parts before he can combine them to form a picture. The first requisite is correct outline—this necessarily requires a knowledge of perspective; next is an acquaintance with the principles of light and shade, artistically termed *chiaro oscuro ;* then a knowledge of the combination of colours; and, lastly, the principles of composition. We shall, therefore, divide our subject into four parts :—1st. OUTLINE, which will embrace elevation and perspective drawing; 2nd. LIGHT and SHADOW ; 3rd. COLOUR ; and 4th. COMPOSITION. Though the main object of this treatise is to convey information for executing drawings of buildings, it is proposed to touch cursorily on landscape in combination with them. The limits of the work will not admit of entering into all the minutiæ of detail necessary to fully carry out the writer's ideas ; he proposes, therefore, to furnish information sufficient to enable the student to comprehend the leading principles of each division of his subject; referring him from time to time to such works and examples as have more deeply entered into their consideration.

All objects are represented in outline by lines, either straight or curved, or by a combination of straight and curved lines together; and the first step towards the acquirement of drawing, and more particularly of that branch of which it is our province to treat, is to attain a knowledge of certain established forms, both regular and irregular, to learn their definitions, and to become acquainted with the rules for drawing them. This first necessary preliminary to the study of drawing, is called PRACTICAL GEOMETRY ; but as the subject is already treated of in the preceding Numbers of this Publication, it would be superfluous to go again over the same ground; the student must therefore make himself thoroughly acquainted with that portion of this Work devoted to the study of Practical Geometry.

There are two different ways of representing Architecture by drawing ;—that of elevation drawing, representing the objects geometrically; and perspective drawing, representing the objects as they appear to the spectator from different points of view. Perspective representations convey a far better notion of objects than elevations, and are consequently used by architects, as examples, to shew the appearance of their designs in execution; but they are not of much practical utility. In perspective drawing, things are represented as they really appear; but strange as it may seem, no form viewed at an angle, save that of a sphere, is ever seen in its positive shape; and as every line of an object drawn perspec-

tively changes its size according to its distance, the proportions of the various parts of a building represented by a perspective drawing would not be available for practical purposes; whereas in elevation or geometrical drawing, every thing is represented in just proportion, either of its real size, or according to a scale. The student must be aware, that if an elevation or geometrical drawing of any very large object were to be made of the real size, it would be difficult, if not impossible, to procure paper and instruments of sufficient magnitude; it is usual therefore, before commencing any drawing, to arrange a scale to draw by, so that all the parts may have their due relative proportion one with another, be the size of their representation what it may; the proportion or size of the scale depending on the judgment of the draughtsman, or fixed on by his employer. To represent a building of the real size of 100 feet, on a scale of one inch to a foot, would require all the necessary tools of a very large size; consequently it would be better to choose a smaller scale, say of $\frac{1}{4}$ or even $\frac{1}{8}$ of an inch to a foot. A scale is commonly given at the bottom or side of any mechanical drawing, to the extent of from 10 to 50 or 100 feet, according to circumstances, for the convenience of measurement in working, and for the advantage of ascertaining any proportions when the drawing is completed. By referring to the plate of the elevation of the principal front and plan of the Athenæum Club House, in Part I. of this Work, the student will find the scale from which it has been drawn, and by which he may ascertain the height or width of any portion of the representation.

Before a perspective drawing of any object can be made, it is necessary, 1st, to have a ground-plan of the building; 2ndly, elevations of those fronts to be represented; and, 3rdly, sections of all the various projections, such as cornices, architraves, mouldings, &c., with their exact measurements. Much less of plan-drawing is required for the purpose of drawing the exterior of a building already constructed, than is necessary for the knowledge of how to construct it; in fact, all that is required is the outline of the outer form of the building, carefully marking all the projections, recesses, spaces for doors and windows, &c. In plan-drawing for construction, the whole of the interior must be carefully laid down, the thickness of walls, doors of communication from one room to another, fire-places, &c. &c. &c., and this on every floor, from the basement to the roof. It must be borne in mind that all measurements of height, both in geometrical and perspective representations, must be made perpendicularly; or, as it is more

familiarly understood, by plum lines; and the measurement of the width of all objects, horizontally, or at right angles to the sides of the building, or to lines parallel with them, as the doors, windows, &c. &c., which are perpendicular. Supposing the student to require to measure the distance between two perpendicular lines; as for instance, to get the width of a door or window. In Fig. 1. are two perpendicular lines, A, B; C is a horizontal line between them. D is a line drawn obliquely between them, and consequently does not give the correct width. The greater the angle made by the oblique line with the horizontal line, the greater would be the inaccuracy; for, as a horizontal line is the shortest distance between two perpendiculars, the more any line between them diverges from the horizontal direction, the greater must be its length. In mechanical or architectural drawing, the eye must not be trusted; and nothing can be depended on but actual measurement. Sections, also, of any parts of a building must always be made vertically or by plum lines; as the section of a moulding of any kind, made in an oblique direction, would materially alter its form.

CHAPTER II.—DIVISION I.

ON OUTLINE.

Plans and Elevations.

Before commencing any mechanical drawing, the learner must provide himself with a proper drawing-board on which to strain his paper; taking care that the bottom edge of his board be perfectly straight, and one of the sides exactly perpendicular to it, or at a right angle.* He must also provide himself with a T

* The best material for making drawing-boards is deal, from that wood taking the paste better than any other. The surface on which the paper is to be laid should be perfectly level, as the slightest warping of the board will interfere with the straightness of the lines. Should the learner be unacquainted with the manner of stretching or mounting his paper,—a most essential operation,—the following directions will be found useful; and it is better to mount the paper double, as in laying on large washes of colour it obviates, in a

square and a pair of compasses or dividers. The T square is a straight flat rule, having at one end a cross piece attached to it, exactly at a right angle, the cross piece being made thicker than the rule inserted into it, in order that it may slide along the edge of the board, the rule always preserving the same direction. (Fig. 2.) The straight rule A, the two sides of which, 2 2, are parallel, is so placed in the cross piece B, as to be perpendicular to the plane 1. (Fig. 3.) A, B, C, D, represent the four sides of a drawing board, of which the side B is perpendicular to the bottom A. If the flat part of the T square, 1, be placed against the edge A of the drawing board, the sides of the rule 2 2, will be perpendicular to the edge A; and if the rule be slid along the edge of the board, and lines ruled from either edge 2 2, as at *a a a*, these lines will be all parallel to each other, and perpendicular to the line A of the board. In like manner, if the edge 1 of the T square be placed against the side B of the drawing board, slid along it, and lines ruled from either edge 2 2, as at *b b b*, these lines will be perpendicular to the side B of the board, parallel to each other, and to the bottom line A. It is seen, then, that the lines *a a a* are perpendicular to the line A; and the lines *b b b* being parallel to the line A, the lines *a a a* are also perpendicular to them. The edge of the T square 1, therefore, being placed against the edge A of the drawing board, and slid along, perpendicular lines may be drawn on any part of the board from the edge 2 of the T square; and the edge of the T square being placed against the edge B of the board, will enable you to draw horizontal lines wherever they may be required. The T square is the readiest and most convenient instrument for drawing all horizontal and perpendicular lines.

As a first essay, let us suppose we have to draw the plan, from which to make an elevation of a cottage standing on a parallelogram of 20 feet by 10, to be

great measure, the paper rising in ridges, or, as it is familiarly called, cockling. Lay on a flat board, or table, a sheet of paper the size of the drawing required, and a second piece about one inch larger every way; saturate both pieces with water by gently sponging them, and then lay the smaller sheet on the larger one, as B on A, (fig. 4), wiping the wet off the surface of the paper with a dry cloth; then, with a large hog's-hair brush, cover the whole exposed surface of the paper with paste made of flour and water only. When thoroughly pasted, remove the upper sheet B, and place the sheet A, the pasted side downward, on your drawing-board, wiping it carefully with a cloth to prevent any bubbles of air remaining underneath; this done, place the sheet B, the pasted side also downward, in the middle of the sheet A, wiping it gently with a cloth, so that every part of the upper piece of paper is in close contact with the under piece; lay it flat till quite dry. It will be obvious to any one, on a little consideration, that when the drawing is completed, it can be cut from the board with a penknife, the edge only of the under sheet, which projects beyond the drawing, adhering to the board.

drawn on a scale of $\frac{1}{4}$ of an inch to a foot.* First draw a horizontal line at the bottom of your paper, on which mark off 10 spaces of $\frac{1}{4}$ of an inch each, (fig. 5). marking them 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; this will answer as a scale for the first 10 feet—and continue it 5 at a time on to 20 or 30, marking them 15, 20, 25, &c.; this done, draw a long horizontal line A B at the lower part of the paper, and measure off on it 20 feet from the scale, as at *a b*, from each of which points draw a perpendicular line, and measure off on each 10 feet of the scale, as at *c* and *d;* join *c* and *d*, and you will have the outer boundary of the parallelogram on which the cottage stands. The walls of the cottage are one foot thick—a distance of one foot of the scale must be measured on each of the lines forming the parallelogram, as at *e*, *f*, *g*, *h;* from each of the points *f* and *h* perpendicular lines must be drawn, and from the points *e* and *g* horizontal lines must also be drawn, forming, by their intersection with the lines drawn from *f* and *h*, a second parallelogram within that first drawn; the space between the two parallelograms representing the thickness of the wall. In the middle of the front of the cottage is a door four feet wide; and midway between each side of the door and the sides of the cottage, a window three feet wide. If eight feet of the scale be measured off from each side of the plan *a* and *b*, as at *i i*, it will leave a space between equal to four feet, to represent the position of the door; from each of the points *i i* a perpendicular line must be drawn, to meet the line of the inner parallelogram; from each side of the door and the sides of the cottage, a distance of two feet and a half must be measured off, as at *k k k k;* this will leave two spaces of three feet wide each, which will represent on the plan the positions of the windows; from each of the four points marked *k*, a perpendicular line must be drawn to meet the inner line, denoting the thickness of the wall. This completes, according to the directions given, the ground-plan of a cottage containing one door and two windows.

We have here drawn more than is absolutely necessary for the mere elevation of the front and side of the cottage we are about to give directions for; but it has been considered desirable to proceed thus far in the directions for the foregoing plan, as they embrace all that is essential for drawing any plan the parts of which

* The examples are for the most part made on a very small scale, for the convenience of printing; so long as they are sufficiently large to avoid any confusion in the references by letters and figures to the points and lines, it is of little moment of what size they are given; but as drawing with accuracy on a very small scale requires considerable practice, the student is advised to make his own drawings on a scale three or four times larger than the figures are here represented.

can be represented by right lines; for, in the same manner that the length, width, and position of what is here laid down have been accomplished, the length, width, and position of any other parts may be represented. The width and position of any partition walls, in their relative position with the outer wall, being known, they might easily be drawn; as also any back door or doors of communication from room to room; their width and distance from any part already drawn being described, may be represented in the same manner as were the positions for the door and windows in the example given. It is usual, after the outline of a plan is completed, to shade that portion of it which represents the wall, leaving the spaces for the door and windows white.

From the plan and description of the dimensions of the different portions of the cottage to be represented, we will now proceed to draw the elevation (Fig. 6.) First draw the horizontal line A, B, on which mark off the points indicating the positions of the sides of the cottage, and the door and windows on the plan marked 1, 2, 3, 4, 5, 6, 7, 8, from each of which points raise perpendicular lines. On each of the two extreme lines representing the outer lines of the wall of the cottage must be measured off the height of the wall, twelve feet, at 9 and 10, and a horizontal line must be drawn between them; this represents the upper line of the wall from which the roof springs. The two middle perpendicular lines drawn from 4 and 5, represent the sides of the door, which must be made seven feet high; measure off on either of the lines seven feet, as at 11 or 12, and from either point draw a horizontal line between the two perpendiculars; this completes the elevation of the doorway. The lower parts of the windows are each of them three feet from the ground, and the windows five feet in height. On either of the lines 2, 3, 6, or 7, measure off three feet for the distance of the windows from the ground, as at 13, 14, 15, or 16, through either of which points between the lines 2 and 7, draw a horizontal line. On any one of the same lines 2, 3, 6, or 7, from either of the points 13, 14, 15, or 16, measure off a distance of five feet, for the height of the windows, as at 17, 18, 19, or 20, and through either of them draw another horizontal line between the lines 2 and 7. The horizontal lines between 13 and 14, and 15 and 16, form the bottom lines of the windows; those between 17 and 18, and 19 and 20, marking the upper lines of the windows. Having accomplished the drawing of an elevation of the wall of the front of a cottage with a door and two windows, let us now proceed to the roof. The roof, as will be seen by the side elevation, is a gable roof; now as all measurements are taken perpendicularly, the height must be measured in a perpendicular

direction from the top of the roof to the ground, the oblique lines or slopes of the roof being left to be shewn in the side elevation. Measure off on the perpendicular line from the point 8, eighteen feet, as at 21, through which draw a horizontal line, carrying it on each side a little beyond the outer lines of the wall of the cottage. The roof of the cottage projects on either side one foot beyond the wall of the cottage; a space of one foot must therefore be measured off on either side of the lines 1, 9, and 8, 10, as at 22, 23, through which draw two perpendicular lines from the top of the roof, drawing each of them below the upper line of the wall. The slope of the roof projects beyond the front of the cottage, one foot perpendicularly below the top of the wall; a distance of one foot must therefore be measured off below the top of the wall on the line 9, 10, as at 24, and a horizontal line drawn through it between the perpendicular lines drawn from the roof through the points 23, 24. Having thus completed the front elevation of the roof, and with what has been before done, the complete outline of the elevation of the front of a cottage, let us now proceed to draw the elevation of one of the sides.

As in the elevation of the front, first draw a horizontal line A B (fig. 7), on which measure off the depth of the cottage from the plan (10 feet), at the extremities of which, 1, 2, raise two perpendicular lines twelve feet high, as at 3, 4, and draw a horizontal line between the two points.* This side, which forms a gable of which the apex is eighteen feet from the ground, the point of the gable situated exactly above the centre of the parallelogram just drawn, must be found, from which the oblique lines to the points 3 and 4 must be drawn. Draw a perpendicular line dividing the parallelogram into two equal parts; (a certain and quick mode of accomplishing this is, by drawing two diagonal lines, from the points 1 to 4, and 2 to 3; the point of intersection of these diagonals is the exact centre of the parallelogram, through which draw the perpendicular line,) and on it measure off the height of eighteen feet; this will be the point marking the apex of the gable, from which draw the sloping lines of the roof, 5 4, 5 3. The roof projecting one foot perpendicularly below the top of the wall, measure off on one of the sides, 3 1 or 4 2, one foot, as at 6, through which draw a horizontal line a little beyond either side of the cottage, and continue the sloping lines of the roof 5 3 and 5 4, till they meet this line at the points 7 and 8, which will complete the elevation of the side front of the cottage.

* This is done in precisely the same manner as the elevation of the front wall of the cottage, (fig. 6.)

The foregoing examples are given with a view only of shewing the rules by which a plan and elevation of a building may be drawn from description, or what is nearly the same thing, from your own design; and the subject chosen is of the most simple kind, intended solely to illustrate the mode of drawing rectangular forms by description; the fewest possible number of lines have been employed, to render the rules for drawing them clearly intelligible; but simple as are the forms and descriptions here given, they contain the essential information necessary for drawing plans and elevations consisting of right lines. According to the number of parts in the subject, many or few points from which to draw the required forms may be necessary; but be they ever so numerous, or ever so few, the rules here given will enable the student to find them. Every line except the mere outline of the different parts has been carefully avoided, to prevent confusion, and for the same reason the chimney has been omitted; but having proceeded thus far, it is easy to add to what is already done, any parts that may be required. Let us take a portion only of fig. 6, (which is all that is required for our purpose), viz. the door, which we will say contains two panels, the upper one, two feet high by three feet wide; the lower one, three feet six inches high by three feet wide; with a frame work round each of the panels six inches wide. Let A, B, C, D, (fig. 8) represent the sides and top and bottom of the door, drawn on double the scale of the preceding figures. On either of the lines D or B, from the ground line, first measure off six inches for the frame work at the bottom of the lower panel at 1, then a space of three feet six inches at 2, for the height of the lower part, above that another space of six inches for the frame work between the two panels at 3, and lastly a space of two feet for the height of the upper panel at 4; this will leave a space of six inches between the point 4, and the top of the door, for the frame work above the upper panel; from each of these points 1, 2, 3, 4, draw a horizontal line to the opposite side of the door; then, on either of the lines A or C, measure off a distance of six inches, at 5, for the width of the frame work; then three feet for the width of the panels at 6, which will leave a space of six inches between that point and the side of the door, for the width of the frame work on this side of the panels; from each of these points 5 and 6, draw a perpendicular line from the top to the bottom of the door, intersecting the horizontal lines at the points 7, 8, 9, 10, 11, 12, 13, 14; by strengthening the horizontal and perpendicular lines between these points, the drawing of the panels and frame work required is completed. In like manner, suppose each window to contain nine panes of glass, if one of the sides

be divided into three equal parts, and the top or bottom line also divided into three equal parts, as in fig. 9, at 1 2 and 3 4, and horizontal and perpendicular lines drawn from each of the points of division, the lines denoting the frame work and the nine equal divisions will be found. In careful drawing, however, this mere division into nine equal parts would not be sufficient, the wood-work containing the panes of glass must also be drawn; this is not attended with any additional difficulty, it requires only care and attention. Let A, B, C, D, represent the outline of the space for the window, and suppose the nine panes of glass to be contained in a frame three inches wide, the bars containing the separate panes being half an inch wide. The following figure (10,) is drawn on a scale four times that of fig. 6. Measure off a space of three inches on each line A, B, C, D, to represent the width of the outer frame, and draw the lines to represent it precisely in the same way as was done in drawing the thickness of the wall in the plan (fig. 5;) divide the inner parallelogram into nine equal parts, as in fig. 9; on each side of the lines forming the divisions of the nine spaces, measure off one quarter of an inch, and draw at that distance, on either side of these lines, parallel lines from top to bottom and from side to side, the intersections of these lines 1, 2, 3, 4, &c. giving the outline of the forms required, half an inch wide.

To the mere skeleton of the plan and elevation, (figs. 4, 5, and 6,) here given, the student will perceive how easily any additions might be made,—with what facility a chimney, portico, or any other object, might be added to the plan, and from the plan to the elevation,—how any window or recess might be added to the side elevation,—the divisions of stones on the walls, or those of slates or tiles on the roof, &c. Sufficient is here considered to be done however for a first attempt, and the representation of cornices, mouldings, and other ornamental work, must be left for future consideration.

CHAPTER III.

Plans and Elevations—(continued.)

THE figures given in Plate I., illustrative of the foregoing matter, contain no drawing of any ornamental projections; and in the simple outline there given of

the windows and door, there is no more than the mere indication of the form and position they would occupy traced on the wall by lines. To shew that the windows or door are not on the same plane as the wall of the cottage, or in other words that they form recesses, would be easily done in a shaded representation, as the shadows, which in architectural drawings are laid in according to regular rule, determine by their depth and width the thickness of the projections that cast them. This is only mentioned incidentally, as we shall treat of light and shade separately.

In referring to any elevation-drawing in simple outline, of which several are to be found in this Work, certain mouldings can only be represented by a series of parallel lines at unequal distances, shewing the perpendicular widths of the different parts of the moulding; but it is impossible from these lines only, to ascertain either the forms of the various parts, whether rectilinear or curvilinear, or the extent of their projection; it is therefore necessary, in order to become acquainted with their forms and projections, to draw sections of them. If lines be merely drawn round any part of a building, such as a door, window, recess, &c., as in fig. 1, Plate II., we know that they represent the lines of a moulding, with the width of its several parts; but in order to shew their form and projection, a section must be drawn from description. Suppose the lines *a b* to represent a rectangular projection of two inches by a perpendicular height of one inch, those of *b c* to represent a convex projection of $1\frac{3}{4}$ inch by $1\frac{3}{4}$ perpendicular, and that of *c d* a semicircular band of $\frac{3}{4}$ of an inch diameter. First draw a perpendicular line A B, (fig. 2),* to represent the plane from which the moulding projects, and at right angles with it draw the line 1 2, two inches long; draw the parallelogram 1, 2, 3, 4, one inch perpendicular height, which will represent a section of the upper projection. With a pair of compasses from the point 4, with a radius of one inch and three quarters, describe the arc of a circle from 5 to 6, this gives the section of the convex moulding; then with half the diameter of the lowest projection, three eighths of an inch, from the point 7 describe the semicircle 6, 8, 9, which gives the section of the bead, the whole forming a section of the moulding, (fig. 1). It is of no moment whether a moulding consist of many or few parts; if the elevation be correctly drawn as to the width of its several parts, and correct descriptions of the form and projection of the different portions be given, any moulding can be drawn from them; always supposing the

* The references to the figures throughout this Chapter must be understood to relate to Plate II.

student to be acquainted with the names of the various forms of the projections, and the rules for drawing them. It is therefore necessary, before proceeding further, that the student make himself acquainted with the names of the different forms, and the mode of representing them.

Mouldings are projections consisting of figures composed of curved and straight lines; the curves vary considerably in their form, particularly those used in the mouldings of Grecian architecture. The curves in Roman architecture are all portions of a circle; in Greek architecture they are portions of the ellipse, parabola, or hyperbola. It has been already stated that all sections for drawings should be made, or supposed to be made, perpendicularly in the case of mouldings, at right angles with the perpendicular or horizontal lines representing them in elevations. In illustration of the necessity for this, we will take certain solids, and shew what a wide difference the form of the section assumes according to the direction in which it is cut. In making a section of a cube, if it be cut parallel to the plane of either of its faces, the form of the section will be a square, (fig. 3); if the slightest deviation be made, so as to take an oblique direction, it will take the form of an oblong, (fig. 4). If a cylinder be cut longitudinally, or at right angles with either end, the section is a rectangular parallelogram, (fig. 5). If it be cut transversely, or parallel with its circular ends, the section will be a circle, (fig. 6); and if cut in an oblique direction, the section will take the form of an ellipse, (fig. 7.) The sections of a cone shew the greatest diversity of form, according to the directions in which they are made. If a cone be cut, passing through the vertex to any part of the base, the section is of the form of a triangle, (fig. 8). If cut transversely, parallel to the plane of the base, at any point between the base and the apex, the section is a circle, (fig. 9). If the section be made obliquely from side to side, the form is that of an ellipse, (fig. 10). When a cone is cut through in a direction parallel to one of its sides, the section is called a parabola, (fig. 11). When the cone is cut from its base, in a direction so that a continuation of the cutting line would meet a continued line of the opposite side of the cone, somewhere above the vertex, the form of the section is an hyperbola, (fig. 12.)

All the forms made by these sections are met with in Architecture, and regular rules are laid down for their construction. Rectilinear figures can be drawn with a ruler; all circles, or portions of circles, may be described with a pair of compasses. There are various modes given in works on practical geometry for drawing ellipses,—by means of the trammel, by fixing nails or pins in

the foci and drawing the curve with a string, by ordinates, &c. &c. For our purpose, the finding certain points through which to draw the curve, by means of the intersections of straight lines, will be found the most desirable, the more especially when we come to treat of perspective drawing;—certain rules for describing them, by points of intersection, will be given in the directions for drawing the curves of mouldings.*

1. The rectilinear portion of a moulding, either above or below, is usually termed a fillet; the way of drawing these has been already explained, *a b*, figs. 1 and 2.

2. Any narrow semicircular portion of a moulding is termed a bead, *c d*, fig. 1.

3. A moulding similar to a bead of a large size, with a fillet above or below it, is termed a torus.

4. When the contour of a moulding is convex, and the curve the segment of a circle equal to or less than a quadrant, it is termed an ovolo; if the contour be convex, and the curve not a portion of a circle, but of some other conic section, it is called Grecian ovolo.

To draw the ovolo: If the contour of the moulding be an exact quadrant, the point of contact with the lines denoting the plane and the projection, will be the centre from which to describe the arc of the circle, as at 4, fig. 2; but if the curve be less than a quadrant, the point will not fall on either line. The two

* In drawing arches, the contour of mouldings, &c., the various curves produced by the different sections of the cone occur so constantly, that the student would do well to make himself acquainted with that portion of practical geometry. The study of practical geometry, in fact, is of such great utility, that he is strongly recommended to make himself thoroughly master of it in all its branches. Many excellent works have been written on the subject, but for those who have not the advantage of a master, the "Complete Course of Practical Geometry," by Major Gen. Sir C. Pasley, will be found most serviceable; it is barely possible to imagine any one so dull of comprehension as not to be able, with moderate attention, to understand the problems, from the simple and clear manner in which they are there described. In writing directions for describing curves, it is almost impossible to avoid certain technical terms; and, as the want of knowledge of these terms may be attended, in our progress, with much inconvenience, a diagram of an ellipse, with certain lines and points, and their definitions, is here given at Fig. 13. A is the transverse axis, or longest diameter; B, a line perpendicular to it, the conjugate axis, or shortest diameter; C, the point of intersection of the axes, the centre of the ellipse. D D, the vertices, the two most distant opposite points of an ellipse, between which the transverse axis always lies; E E, points on the transverse axis called the foci, found by intersections of the arcs of circles, described from the extremity of the conjugate axis, with the radius of the semi-transverse axis; any straight line passing through the centre, and touching the curve on either side, is a diameter, as F, (the transverse and conjugate axes are both diameters). Any line drawn from a diameter to the curve, parallel to a tangent, as G G, touching the extremity of the diameter, is called an ordinate, as H H; if an ordinate be continued through, to meet the curve on the opposite side, it is called a double ordinate, as J.

points being given, A and B, (fig. 14), between which the curve is to be drawn, with the length of a straight line between these points as a radius, draw from either point the arc of a circle, intersecting each other at C, from which point, as a centre, with the same radius, describe the curve A D B, which is the required form.

If the convex moulding be the quarter of an ellipse, the length of the projection will be the semi-transverse axis, the perpendicular height of the moulding the semi-conjugate. Let A B, (fig. 15), be the length of the projection, and B C the width of the moulding. Construct the parallelogram A B C D, and draw the whole length of the transverse axis to E. Divide the semi-conjugate axis into any number of equal parts, numbering the points of division from the bottom upwards, as at 1, 2, 3, 4, 5, 6, 7. Divide the line D C (which is of the same length as the semi-transverse axis) into the same number of equal parts as the semi-conjugate B C, numbering the points of division from right to left, as 1, 2, 3, 4, 5, 6, 7. From each of the points on D C draw a line to the vertex A of the ellipse, and from the opposite vertex E, through each of the points of division on the semi-conjugate axis, draw a line to intersect those already drawn at the points 9, 10, 11, 12, 13, 14, 15, through which points draw a curve, which will be the contour required. It must be evident to the learner that the greater the number of points, the more correct will be the curve. The projection here given is much longer than the depth of the moulding; but if this were reversed the mode of drawing would be similar, the contour taking the appearance of an upright ellipse, instead of a horizontal one. (See fig. 16.)

5. If the contour of a moulding be the exact reverse of an ovolo, that is concave, instead of convex, and equal to or less than a quadrant, it is called a cavetto, (fig. 17.) This is drawn in the same manner as the ovolo, (fig. 2), with this difference only, that the central point 4, (fig. 2,) from which to draw the curve, is found on the opposite side, as at *a*, (fig. 17).

6. When the contour of a concave moulding is a semi-ellipse, it is called a scotia, and is drawn by the same rule as fig. 15, the divisions being made on the opposite lines. By looking at fig. 15 upside down, the mode of drawing the curve this way will be seen.

7. If the contour of a moulding be partly convex and partly concave, it is called a cimatium. When the convex part of the contour projects beyond the concave, it is called a cima reversa or ogee curve; if the reverse be the case, that the concave projects beyond the convex, it is called a cima recta. Let

A B, (fig. 8), represent the projection of a cima reversa, and B C the perpendicular height of the moulding. From A to C draw a right line, and divide it into two equal parts at D; from each of the points A and D, with the radius A D, describe an arc of a circle intersecting each other at E, from which point describe the arc A F D; from the points D and E, with the same radius, describe two arcs on the opposite side, intersecting each other at G, from which point describe the curve D H C, which will complete the contour of the ogee or cima reversa. The cima recta is drawn in a manner precisely similar, describing the concave portion at the top and the convex at the bottom.

If the curves of the contour be not parts of a circle, but portions of an ellipse, they may be drawn by the same rule as that described in fig. 15. Let A B, (fig. 19.) be the projection, and B C, the depth of a cima recta moulding, the curve of which is formed by two quadrants of an ellipse. Construct the parallelogram A, B, C, D, which divide into four equal parts. In the upper division, to the left, describe the concave quadrant of an ellipse by the rule given in fig. 15. In the lower division to the right, describe the convex quadrant of an ellipse. The two quadrants will give the contour of the moulding required. By reversing the order of drawing the two quadrants, putting the convex in place of the concave and vice versa, the curve will be that of a cima reversa.

The foregoing are general rules for drawing the contour of mouldings, but the student will find on examination of different buildings or representations of them, that the form of the mouldings presents an almost endless variety; our space does not admit of giving more than the ordinary examples; a thorough acquaintance with practical geometry will however enable the student to draw any form of moulding. In addition to the directions already given for drawing elliptic curves, the following, as a general rule for describing the curves of conic sections in mouldings, when certain points are given, will be found useful. Let A (fig. 20.) be the extreme projection of the curve, and B the point of contact of a tangent B C, at the bottom of the moulding. Draw the line B D, a continuation of the upper line of the lower fillet, to the length of the projection at D, from which point draw a perpendicular line to A, cutting the tangent B C, at the point C, which will complete the parallelogram A E B D. Continue the line B E, to F, and make E F equal to E B. On the same line from the point E, set up the distance from D to C, at G, making E G equal to D C; draw a line from A to G. Divide each of the lines A G and A C, into a like number of equal parts, numbering the points of division on each line from the point A.

draw lines intersecting those drawn from A C to B, at the points 6, 7, 8, 9, 10, which are the points through which to draw the curve. Fig. 21. represents a curve drawn in the same manner, but of a different form; the flatness or roundness of the contour depending on the point at which the tangent B C intersects the line A D. If the distance from A to C be less than one half of the line A D, the curve is elliptic; if the distance be exactly one half, the curve is parabolic; if more than half, it is hyperbolic.

In architraves, cornices, capitals of columns, &c., when the mouldings project from the side the same as from the front, the projection and form of the mouldings are shown in elevation drawings, by representing a section of them on the side. In drawing the elevation of a column, the form of the moulding of the capital which projects equally all round, is represented on either side of the lines denoting the diameter of the shaft; so likewise in architraves and cornices, the horizontal lines representing the perpendicular height of the mouldings, are carried beyond the line of the wall, the extent of the projections is marked on the several lines, and the contour of the mouldings is drawn according to description from the projecting points.

From the information contained in the preceding pages, let us proceed to draw a plan with the front and side elevation of a portico and steps.

Let *a a* (fig. 1, Plate III.), represent the front wall of the building (or fascia) with a space *b* for a door-way.*

c c. The plan of the outer walls from which the side walls of the portico spring.

d d. The side walls of the portico, with spaces for windows in each.

e e. Plan of the pilasters and plinth.

f f. Plan of the pilasters and plinth at the back, half the depth of those in front.

g. Plan of the stairing.

h h. Plan of the coping at each side of the steps.

From the above plan and the following description, proceed to draw the front elevation, (fig 2). First draw a horizontal line A B, and an upright line C D perpendicular to it, as lines of projection on which to make all the required

* The dimensions of the various parts are not specified, as they may be found by measurement from the scale at the bottom of the plate, a quarter of an inch to a foot.

measurements.* On the line A B mark the distance between the outer lines of the wall *c c* of the plan, at 1, 1, and from each of the points draw a perpendicular line through the base line of the building E, to represent the outer lines of the sides of the wall; on the line C D, from the base line E, put up the distance at 2; from this point, which determines the height of the lines 1, 1, draw a horizontal line shewing between these lines the top line of the upper flag-stone of the steps, and the upper line of the outer walls. On either side of the points 1, 1, on A B measure off the width of the plinth and pilaster at the several points marked 3, 4, through each of which points draw perpendicular lines. On the line C D measure off the height of the plinth at 5, that of the cavetto moulding at 6, and that of the fillet at 7; from each of which points draw horizontal lines: that from 5, between the lines 3, 3, gives the drawing of the plinth of the pilaster; that from 6, the perpendicular height of the cavetto moulding; and that from 7, the perpendicular height of the bead: these parts to be drawn as before described in treating of mouldings. From the point 8 on the line C D set up the height of the shafts of the pilasters, from which draw a horizontal line, which will complete the drawing of the shafts where it passes between the perpendicular lines drawn from the points marked 4 on A B. Above the point 8, measure off a space for the height of the capital of the pilaster at 9, from which draw a horizontal line. Between the points 8 and 9 on the line D C, mark off the perpendicular heights of the various parts of the capital† at 10, 11, 12, 13, 14, 15, and from each of these points draw a horizontal line entirely across the elevation, to give the height of the various parts on each pilaster;‡ their projections must be measured off on either side, from the continuation of the lines representing the sides of the shaft as at *a*, *b*, *c*, &c., and the contour of the mouldings drawn from point to point. From the point 9 set up the whole height of the superstructure at 16, and between these points 9 and 16 mark off the perpendicular heights of all the intermediate parts, carrying a horizontal line from each across the elevation. The sides of this superstructure are perpendicularly over the outer

* This mode of using lines of projection for the width and height of the various parts to be drawn will be found generally useful, as it obviates the necessity of pricking holes with the dividers, or making a multitude of marks on the drawing itself.

† In the following chapter, which will contain directions for drawing the different orders of architecture, the various parts of a column, capital, &c., will be described: it must suffice here to copy the forms given.

‡ The lines in the example are not carried right across, the right hand side has all the lines left that were employed to make the elevation; on the left hand side they are erased.

lines of the pilasters, these lines must therefore be continued through to the top, and the length of the projection of the several parts set off on either side at the points *d*, *e*, *f*, &c., and the forms of the different mouldings drawn from them. On the line A B, from the plan mark the position and width of the doorway at 17, 17, from each of which points raise two perpendicular lines;* put up the height of the doorway on C D, at 18, either its height from the base line E, or from the top of the upper flag of the steps at 2, and draw a horizontal line from the point 18 between the upright lines of the sides; this completes the front elevation above the steps. On the line of projection A B, mark from the plan the several points 19, 20, for the square post and base, forming the front of the side walls of the steps, carryingup a perpendicular line from each, and on the line of projection C D, measure off the heights of the different parts, between the line E and the point 21; draw horizontal lines from each, intersecting the perpendiculars from 19, 20, measuring the projecting parts from the side lines of the post drawn from 20, 20. Mark the height 22 on C D, where the sloping part of the coping meets the pilaster, and draw a horizontal line across; find the width of the wall, from the points 23 on A B; the lines of the coping on either side, which in the elevation drawing come perpendicularly over the sides of the part drawn from 20, 20; above the point 21, and below 22, measure off a space the width of the projection of the coping 24, 24, on C D, and from them draw two horizontal lines; where the upper one intersects the outer lines of the coping, and the lower one the inner lines, will be the points for drawing the oblique lines of the coping. Divide the space between the base line E and the point 2 on C D, into six equal parts, from the points of division draw horizontal lines to represent the height of the steps, shewing by the perpendicular lines drawn from 25, 25, on A B, that the first step has the greatest projection, as shewn in the plan at D. Set up the height of one step above the point 2, on C D, and from it draw a horizontal line between the sides of the doorway, to represent one step within, and the front elevation is completed.

In drawing the side elevation (fig. 3.) proceed precisely as in the front elevation. The line of projection C D is placed between the two elevations in order that the perpendicular heights of the same parts represented in fig. 2. may serve

* The lines are represented in the plate, drawn from the points on A B, right through, to shew clearly the way in which the distances are got in the elevation; but it is not necessary that the lines should be drawn beyond their absolute length. The points being fixed on the line of projection, the T square may be placed against them, and the lines drawn only where they are intended to represent the object, as is shewn on the left side of the door, and in fact on the whole of the left side of the elevation.

for fig. 3. Thus in executing a drawing of arches, columns, &c. of the same form and size, one line of projection will serve for all. In order to avoid confusion between the two elevations, the references to all those parts that relate to the side elevation only, are put, both in figs. 1 and 3, in capital letters. It is unnecessary to go over again the pilasters, superstructure, &c.; we will proceed at once to those parts distinct from what has been described, fig. 2. Set off on the line of projection, A the face of the wall of the building, B the projection of the wall on which the portico stands, C the projection of the base of the post of the side wall of the steps, D the projection of the forwardest step; through each of these points draw perpendicular lines to their respective heights determined by the lines from the points denoting the heights of the different parts on D C, carried through from the front elevation. Mark on the line of projection the points E and F, the position and width of the window, through each of which points draw two perpendicular lines. Mark on the line C D, at G, the height of the bottom of the window, and at H the height of the perpendicular lines of the sides, and draw horizontal lines from each of the points; from the centre O of that part of the upper line, passing between the lines drawn from E and F, with a radius of half the width of the window, describe the semicircular top; on either side of the points E and F measure off the width of the moulding round the window J K, from which draw up the perpendiculars; below the point G at L place the width of the moulding at the bottom of the window, from which draw a horizontal line. From the centre O describe the outer semicircle of the top of the window. Measure off on the line C D, from the point 9, the depth of the key-stone at M, from which draw a horizontal line, mark the width at the top and bottom, and draw the inclined lines.* The points for all parts of the side elevation similar to those drawn in the front elevation, fig. 1, are marked on the horizontal line of projection, and figured the same as those in fig. 2; but the lines have been erased. The perpendicular heights are already marked on the line D C, and the horizontal lines determining the height of the various parts in fig. 2, are carried through to fig. 3, so that the side elevation may be completed without additional directions.

The space allotted to this portion of the work, (Drawing), is unavoidably so limited, that plans and elevations of all the different parts of the interior of a building would occupy more than could be spared from other necessary subjects;

* There are rules for drawing the inclination of the lines of stones surrounding arches, which are treated of in Practical Geometry.

neither is it exactly the province of the writer to enter into all such minutiæ; it belongs rather to the teacher of building; the information already given being sufficient for drawing the plan of any part of a building, the form and position of which is understood. To those however who may be desirous of exercising themselves on the preceding instructions, ample opportunity is afforded in other portions of this work; the plans, elevations, and sections of a door and window of the Arthur Club-house, Part II.; the plan, section, and elevation of a shop-front in Mount Street, also in Part II.; and interspersed throughout the work, the plans, sections, and elevations of various buildings and their separate parts in detail, will give ample employment and afford excellent information to the student at this stage. We will proceed to the drawing of the several parts of the different orders of architecture, endeavouring to point out the distinguishing features in each.

CHAPTER IV.

ON THE GRECIAN AND ROMAN ORDERS.

In architecture, so various are the styles, and so much variety is to be found in each, according to the period in which it has been used, and the purpose to which the structure has been applied, that to become thoroughly acquainted with the subject, requires a life of study; there are the Egyptian, the Hindoo, the Grecian, the Roman, the Arabesque, the Gothic or pointed style, &c., all distinct from each other, and each possessing its peculiar attributes. We are much indebted to our predecessors for their patient researches, and to our contemporaries who have so far reduced these researches into a system, as to enable us to understand and appreciate with comparative ease the beauties of the constructions of former ages. Simplicity and harmony constitute the great excellencies of architecture; and for these qualities the Grecian styles perhaps stand unrivalled.

Certain arrangements of certain solids, from which stand out various projections, supported on columns, the form and magnitude of the parts bearing a relative proportion one with another, according to rules deduced from

ancient models, the leading features of which vary so as to admit of their being classed under different heads, are denominated orders of architecture. In the Grecian style these have been arranged under three heads, viz., 1. The Doric, so called from the earliest specimens having been found in the Dorian States; 2. The Ionic, taking its name from the earlier prototypes being found in Ionia; and 3. The Corinthian, from this style having been first invented and used in the neighbourhood of Corinth. The Romans however, not satisfied with the beauty and simplicity of the Greek models, have made use of the three Grecian orders, materially altering their proportions, and have added to them two other orders: the Tuscan, which may be considered a mere modification of the Doric, and the Composite, a mixture of the Ionic and the Corinthian.

Each order of architecture has necessarily some of its parts distinct from those of the others, but there are certain definitions that belong to all, with the terms of which it is necessary to be acquainted before the descriptions of the several orders can be understood; such as,

1. The Column. The whole of the pillar supporting the superstructure; divided into—

The Base; an assemblage of mouldings surrounding the lower part of the column.

The Capital; an assemblage of mouldings surrounding the upper part of the column.

The Shaft; the plain part of the column between the base and the capital.

2. The Entablature. The horizontal portion of a structure resting on the columns, divided into—

The Architrave; the lowest portion; that which comes in contact with the uppermost portion of the column; also called epistylium, or epistyle.

The Frieze; the middle portion of the entablature, on which any ornamental sculpture is displayed. It goes also by the name of Zoophorus.

The Cornice; the highest portion of the entablature, resting on the frieze.

3. Diameter. The scale from which the measurements of the various parts of an order are taken; divided into—

Module; half a diameter.

Minute; the sixtieth part of a diameter.

Note.—The diameter of the *base* of the shaft, with its subdivisions, is the scale commonly made use of for the several parts of a columnar structure; thus in speaking of an entablature or any other part, its height is said to be so many

diameters or modules, and so many minutes, instead of so many feet and inches. The diameter of the top of the shaft, from its position, is called the superior diameter ; and that of the base, the inferior diameter. The latter is, however, the longest, as the shaft invariably tapers upwards. In speaking of a diameter as a scale of measurement, the inferior or lower diameter is always intended.

4. Abacus. The square tablet at the top of a Doric column, on which the architrave is placed. The uppermost portions of the other columns on which the entablature rests are also so termed, but strictly speaking the abacus applies to the Doric.

5. Intercolumniation. The shortest distance between the base of one column to the base of the next.

The first, which is the most simple and the most symmetrical of the Grecian orders, is the Doric, of which the following is a general description. The whole structure from the base to the top of the entablature, is divided into three parts. The individual parts here mentioned may be understood by referring to Plate IV., figs. 1 and 3. First, The steps, on the upper slab of which the columns are placed, termed the stylobate, being in general proportion about half a diameter. Second, The column, including the capital and shaft, varying in different examples from four to six diameters in height, of which the capital takes about half a diameter, the shaft gradually diminishing from the base to the top ; the upper diameter being from about two-thirds to four-fifths of the lower diameter. The capital is also divided into several parts; the necking or hypotrachelion, that portion of the column from the upper groove to the lower ring, occupying the space of about one-fifth the height of the capital ; the echinus or ovolo, with the rings, called annulets, in perpendicular height about two-fifths of the capital; and the abacus, also taking about two-fifths. Third, The entablature, varying in its proportions to the column of from one and three quarters to a little beyond two diameters. It has three principal divisions: 1. The architrave, about two-fifths the height of the entablature, its face being perpendicularly over the outer extremity of the inferior diameter, and having at its upper part a projecting fillet called the tænia, about one-tenth of the architrave, under which at regular intervals are projections called regulæ, from each of which depend six small drops or guttæ, the height of the regulæ with the guttæ being the same as the tænia. 2. The frieze, about two-fifths of the entablature, is bounded on the top by a slightly projecting fascia about a seventh or eighth part of the height of the frieze, the remaining portion of the frieze being divided horizontally into spaces

termed alternately triglyph and metope. The triglyph, the plan of which is given figs. 3 and 4, Pl. III., projects a little in front of the metopes, which latter are frequently ornamented with sculptures.* 3. The cornice, about one-fifth of the entablature, consists of three parts ; the mutules, similar to the regulæ of the architrave, each also having six guttæ depending from it, with a slightly projecting fillet above them; the mutules, guttæ, and fillet, taking about one fourth of the cornice. The mutules project from the face of the entablature about two-thirds of their length, not at right angles, but in a sloping direction, as shewn in fig. 3, Pl. III., and having two other rows of six guttæ each, at equal distances from the front row shown in the elevation. The corona, the second division, taking two fourths of the cornice, and the remaining fourth to a combination of mouldings, forming the third division, varying in the different examples, but finished by a fillet at the top. The length of the regulæ and mutules is decided by the triglyphs, one of the former being placed under, and one of the latter above, each triglyph; the number of the mutules, with their guttæ, is more than that of the regulæ, one being placed immediately over the centre of each of the metopes. The triglyphs are so arranged that the middle of the triglyph must come on the centre line of each column over which it is placed, excepting at the two extremities of the frieze, when one side of the triglyph must come over the centre line of the column, and the other perpendicularly over the angle of the architrave.

The descriptions here given are an average of proportions, derived from a comparison of the most approved ancient relics. The proportions of the several parts in the plate are such as to render the drawing of it as simple as possible; at the conclusion of the subject, the student will be referred to authorities from which, by actual measurement, he will be enabled to draw any individual example of Grecian architecture.

Fig. 1, Plate IV., is the elevation of a Grecian Doric column, standing on the stylobate and supporting the entablature. First draw a horizontal line A B, at discretion, to represent the inferior diameter of the shaft of the column, from the centre of which draw up a long perpendicular line on which to measure the perpendicular distances. Make a right line at the foot of your drawing, fig. 2, which divide into two or three equal parts, each of the length of the line A B, and subdivide one of the divisions into sixty parts, to serve for a scale. From

* A part of the celebrated sculptures, known to every visitor of the British Museum by the name of the Elgin marbles, formed a portion of the frieze of the Parthenon at Athens.

the point C on the line C D, measure off six diameters at E for the height of the column; through which draw a horizontal line. From the point E measure down half a diameter at F for the height of the capital, and through this point draw another horizontal line. The diameter of the shaft at the top F is one quarter less than that of the base; measure off then, on either side of the point F, a space of three eighths of a diameter, or twenty-two and a half minutes, at G and H; draw the lines G A and H B, which will give the outer form of the shaft. Mark off from the point E two diameters at D, for the height of the entablature; giving three quarters of a diameter, or 45 minutes, to the architrave from E to J, an equal distance to the frieze from J to K, and half a diameter to the cornice from K to D; through each of which points draw horizontal lines, and draw the outer line of the architrave perpendicularly over the outer point of the lower diameter. In order more clearly to understand the different parts, the capital of the column and the entablature are drawn at fig. 3. on a scale three times the size of that of fig. 1; lettering the parts the same up to the letter K. Divide the space allotted to the capital from E to F, into five equal parts as between *a b;* on the line L (fig. 3.) take one fifth of these divisions for the neck (hypotrachelion) of the capital, two fifths for the annulets and the echinus or ovolo, and the remaining two-fifths for the height of the abacus. Divide that portion allotted to the echinus and annulets into four equal parts, as at *c d*, giving one fourth of the distance for the annulets, and the remaining three-fourths to the echinus; divide the space allotted to the annulets, of which there are three, into three equal parts at *e f*, and subdivide these again for the convenience of drawing the annulets; through all these points above described draw horizontal lines across the space for the capital. Make the width of the abacus one diameter twelve minutes, by measuring off on either side of the point E at N and O, one module six minutes (or thirty-six minutes), and draw from them two perpendiculars to the line determining its height. From the points G H, from whence the neck of the capital springs, continue the sides from the top of the shaft perpendicularly for about three-fourths the height of the neck, when curve the lines outwards to meet the points P and Q on the upper line of the top annulet from where the echinus commences. Find the greatest point of projection of the echinus on either side, and from that point and the point P or Q describe the contour as directed, figs. 20 and 21, Plate II. It will be seen that though the echinus springs from the point Q, from its commencement at the lower line of the abacus, if the line were continued through to the point H, it would form

a cimatium; it is in fact a cima reversa encompassed by three rings; from this curved line on the lines already drawn denoting the width of the rings draw their contour; a section of them is given fig. 4, that the form may be more clearly understood. Though the proportions may vary, any Grecian Doric capital may be drawn by the foregoing directions. Divide the height of the architrave E to J into ten equal parts as from *b* to *g*, of which give the uppermost tenth for the fillet called the tænia, and the next tenth for the regulæ with the guttæ, drawing the tænia to project beyond the architrave two minutes and a half. The width of the regulæ depending on the horizontal divisions of the frieze, we must return to them after drawing the triglyphs. Divide the height of the frieze from J to K into eight equal parts, as from *g* to *h*, of which take the upper eighth for a fillet, having a slight projection called the capital of the triglyphs, the remaining seven eighths being divided into alternate spaces called triglyph and metope. The inner line of the first triglyph comes immediately over the vertical line of the column, the outer line over the outer point of the diameter; draw the outer line perpendicularly over the outer line of the architrave, and the inner perpendicularly over the middle of the diameter of the shaft. In order better to understand the form of the triglyph, a horizontal section is given at fig. 4, Plate III., where the divisions in an elevation would be equal. Fig. 5, Plate III., is a section, in the elevation of which the flat faces would be a little broader than the angular recesses. The two angular channels *a a*, (figs. 4 and 5), are called glyphs; the two half channels on either side *b b*, hemi-glyphs, making three in each figure; hence its name, tri-glyph. In the example before us, fig. 4 is chosen; the space between the outer and inner lines must be divided into nine equal parts, and through each point of division a perpendicular line drawn, which is all that can be shewn of a triglyph in an outline elevation. The top of each glyph is sometimes terminated by straight lines, sometimes by curves, as is shewn on that partly drawn to the right. From the inner line of the triglyph measure off the width of the metope; the metopes are generally square, or nearly so; set off therefore, from the inner boundary of the triglyph, the height of the frieze for the width of the metope, and at that distance draw a perpendicular line for the commencement of another triglyph. The length of the regulæ depending on that of the triglyphs, may now be put in; give two-thirds of the distance allotted for the regulæ and guttæ for the depth of the regulæ, and draw perpendicularly under the outer lines of the triglyph its boundary lines; divide the space left for the guttæ, which is equal to the regula, into eleven parts, six equal parts for the guttæ, and five for the intervals between

them, making the latter a little wider than the former; mark the points for the guttæ and their intervals alternately, and draw their perpendicular sides. The cornice from K to D is divided into so many unequal parts, that we must take each part separately; first, immediately over the frieze draw a bead one minute thick, and above this mark off the space for the mutules, with their guttæ, four minutes and a half (the same height as the regulæ and guttæ), place the mutule immediately over the triglyph, as the regula is placed under, and draw it every way similar; the face of it, being one and the same, the situation only excepted, being placed above instead of below. Over the centre of the metope, another mutule, with its depending guttæ, similar to that over the triglyph, must be drawn, and so on over every triglyph and metope in an elevation. The projection of the mutule is two-thirds of its length beyond the face of the architrave, not at right angles, as seen by the projection of a side mutule, but at an inclination, which shews also the first of each of the three rows of guttæ. Above the mutules draw a fillet one minute and a half wide, projecting beyond the mutules half a minute; above this draw the corona, ten minutes in height, projecting beyond the fillet below one minute; above the corona draw a narrow fillet half a minute high, and again above this a small echinus two minutes and a half high, having its greatest projection beyond the corona two minutes and a half; over the echinus a fillet two and a half minutes high, projecting half a minute beyond the echinus; above the last fillet draw a broader echinus six minutes high, with a projection of six minutes; and above all a fillet two minutes high, projecting one minute and a half beyond the echinus.

The circumference of the shaft is divided into twenty equal parts, each division being slightly hollowed; these are called flutes. Fig. 6, Plate III., represents the horizontal section of a column with twenty flutes. To draw the flutes of a column, describe a circle, the diameter of which shall be the same length as that of the shaft; divide the circumference into as many equal parts as there are flutes in the column, in this instance twenty.

In making the divisions for the lines, to represent the edges of the flutes on the shaft, there will be nine whole flutings to represent, and a half-fluting on each side. The diameter A B, (fig. 6, Plate III.), must be drawn parallel to the horizontal lines of the elevation, and the diameter C D at right angles with it; the divisions for the flutes on the circumference must be so arranged that each of the extremities of these diameters must come in the middle of the space for a flute. Let E F represent the diameter of the shaft on which the flutes are to be

drawn, the points E and F being placed perpendicularly over the points A B. From each of the points of division for the flutes 1, 2, 3, 4, &c., on the semi-circumference A D B, draw a perpendicular line to the diameter E F; lines drawn from these points, the length of the shaft, will give the correct diminution in the apparent width of the flutes in the elevation of a column; bearing in mind that, as the shaft is narrower at the top than at the bottom, both the superior and inferior diameters must be divided into a like number of parts, and lines ruled the whole length of the shaft from the corresponding points. The number of flutes varies in different examples; being in some more, in others less than twenty. The points *a a a* shew the centres for drawing the curves of the flutes. The rule given in the problem, fig. 10, Plate III., in Practical Geometry, will enable the student to find these points, whether the concavity is great or little.

The stylobate, the perpendicular height of which is half a diameter, must be divided into three equal parts for the width of the steps; horizontal lines must be drawn through each point of division; the projection of the upper step in front of the columns, and the projection of the two steps below must be marked off, and perpendicular lines drawn from each point, which will complete the elevation of an example of Grecian Doric. It has been the Author's endeavour to make the necessary directions for drawing this elevation as intelligible as possible, at the risk of being, by many, considered too prolix; but these directions will be ample to enable the student to draw any example of Doric, and the greater portion of either of the other orders of architecture. An example will be given of each of the other orders, with the measurement of their several parts, and the directions for drawing them will be necessary for those parts only which form the distinguishing features of the order. It will be seen by comparison of the elevations, Plates IV. and VI., though only one example of each order is given, that the form of the capital of the column constitutes the most essential distinction of an order, both in the Grecian and Roman styles. The rectangular abacus, with the echinus and rings denoting the Doric; spirals at either end of the capital, immediately under the abacus, forming what are termed volutes, denoting the Ionic capital, fig. 1, Plate VI. Foliage composed of rows of leaves surrounding the capital with tendrils terminating in volutes, form the distinguishing features of the Corinthian, (fig. 2, Plate VI.) The terms made use of for the several mouldings are the same in all the orders, as also the names of the several parts, as column, entablature, &c., with their subdivisions. In the Ionic and Corinthian orders, the lower part of the shaft of the column where it joins the base forms a concave sweep,

similar to the cavetto, from the top of which the shaft springs; it is termed the apophyge. In the fluting of the columns of these orders, it will be observed that instead of the divisions between the flutes coming to an edge, the intervals form a fillet, the fillets being usually about one fourth, a little more or less, the width of the flutes. The mode of drawing these is similar to that given for drawing the flutes of the Doric column, (fig. 6. Plate III.); with this addition, that whatever may be the number of flutes, there must be an equal number of fillets; the circumference must therefore be divided into so many parts for flutes and a like number for fillets, (fig. 1, Plate V.,)* placing them alternately, taking care always that the centre of the flutes comes on the lines of the diameters as described fig. 6, Plate III. The curves of the flutes when elliptical must be drawn by joining the extremes of the curve by a straight line, to serve as a transverse diameter, from the centre of which a perpendicular line must be drawn inwards, to the full depth of the concavity, to serve as a semi conjugate diameter.

To draw an Ionic elevation, proceed in precisely the same manner as in that of the Doric. Divide the three principal parts, stylobate, column, and entablature, into their several component parts, according to the measurements given in the plate. The base of the column, which is not found in the Doric, consists of a series of mouldings already described; the entablature presents a fresh feature in the rectangular parts called dentils, which may also be drawn without further directions;—any ornamental work on the mouldings must be for after consideration, when we treat of drawing foliage, &c. The main point in the representation of the Ionic order is to describe the spiral lines forming the volutes. A variety of modes are given by different authors for the construction of spirals; some recommending the drawing the curve through certain points; others, the finding certain points as centres from which to describe a series of quadrants of circles. We give one example of each mode of describing a spiral.

Let A (fig. 2, Plate V.) represent the centre of the spiral, and B its greatest distance from the centre; from the point A as a centre, with the radius A B, describe a circle. Divide the circumference into any number of equal parts, (in the example ten is chosen), and from the centre A to each of the points of di-

* In the plan of the half shaft here given, the column is represented as having but twelve flutings. From the unavoidably small size of our figures this number will enable the student to understand more clearly the figure than if it had been represented with twenty-four.

vision draw a straight line, as A *a*, A *b*, A *c*, &c. Divide the radius A B into the same number of parts as there are to be revolutions of the curve, (in this case three), and divide each third into as many equal parts as the circumference has been divided into, (ten), which will give thirty divisions on the line A B; measure from A towards *a* twenty-nine of these divisions, from A towards *b* twenty-eight, from A towards *c* twenty-seven, and so on round and round, making each radius less by one thirtieth till you arrive at the centre, figuring each with the number of divisions, as at twenty-nine A *a*, twenty-eight A *b*, &c. &c. Through each of these points, commencing at B, (the greatest height of the volute), draw by hand a continuous curve, till you arrive at the centre-point A, which will describe the spiral. The number of divisions depends entirely on the pleasure of the draughtsman; in small spirals, the division of the circumference into ten parts will be found quite sufficient; where the spiral is large, and great accuracy is required, the number of divisions must be increased.

To draw a spiral, of a given height, to meet the circle in the centre, (called the eye), to any number of revolutions. Let A B (fig. 3, Plate V.) represent the whole height of the proposed spiral; cut off from the end of it the length of the diameter of the eye, at C; divide the remainder, C to A, into as many equal parts as there are to be revolutions in the spiral, and subdivide each of these parts into four equal parts, so that the line from A to C is divided into four times as many equal parts as there are revolutions in the spiral. Three revolutions are here proposed. With a radius of half B C describe a circle to represent the eye of the volute, through the centre O of which draw a horizontal line and a long perpendicular line; set up on this perpendicular line, at D, half the length of the line from A to C with one division added to it, (seven twelfths of A C), and also one half the diameter of the eye; this will give the extreme distance at which the revolutions terminate from the centre. Take a distance of half of one of the divisions of A C, (one twenty-fourth), and set it up on this perpendicular at *a*,* through which point draw a horizontal line, and measure off on either side a space equal to that from the centre to *a*, at *b* and *c*, from each of which points draw diagonal lines to the centre. From the points *b* and *c* draw down perpendicular lines, cutting the semi-diameters of the eye into two parts at *d* and *e*; divide each of the spaces from O to *e* and O to *d* into as many equal parts as there are to be revolutions, and according to which side the volute is to be represented,

* This part being extremely minute, the figure for finding the centres is given on a larger scale, (see fig. 4.)

divide on that side the nearest of these divisions into two equal parts, as at *f*; from this point, parallel to *b* O and *c* O, draw the diagonal lines *f h* and *f g*; through each of the points of division on *d* O and *e* O, perpendicular lines must be drawn, cutting the diagonal lines at the points *i k l m n o p q*; join the opposite points on each diagonal, and you have the centres required for describing the spiral with the compasses, equal in number to the divisions on the line from A to C,—a quadrant from each centre;—twelve quadrants necessarily producing three revolutions, the number proposed. From the point *c* as a centre, with the radius *a* D, draw the arc of a circle till it meets the continued line *c a b* at G, which forms the first quadrant F *c* G; from the point *b* as a centre, with the radius *b* G, describe from the point G the arc of a circle till it meets the continuation of the line *b d g* at H, which will form the second quadrant G *b* H; from the point *g*, with the radius *g* H, describe the third quadrant H *g* J, and so on, taking the points for centres in the order they are lettered, when the last quadrant from the point *q* will touch the inner circle (the eye) on the perpendicular line above *a* at *r*. It is to be hoped the student clearly understands the mode here given for drawing spirals, and that, whatever may be the number of revolutions, he would be enabled to describe them; were there twenty revolutions the process would be precisely the same, the number of centres only being increased. To draw a spiral with twenty revolutions would require eighty centres, from which to describe the quadrants; more lines would of necessity be required; but if the spaces from *d* to O and *e* to O were each divided into twenty parts, and perpendicular lines drawn through each to meet the diagonals, the twenty centres would be as easily found as in the foregoing example. Fig. 5 is a diagram, shewing the centres for describing a spiral of five revolutions. The diameter of the eye being given with the height of the spiral, the length of the line *a* O is assumed. All proceeds the same as in the former example, and the points from which to describe the quadrants are lettered consecutively from the first centre to the last.

The volute is composed of many spirals one within another, the lines of the curves gradually approaching each other till they meet at the same point on the eye. In the example before us the line from the centre O to D is the greatest distance of the spiral; if the half diameter of the eye be taken from it there remains a space *r* D, consisting of seven equal parts taken from A B. Suppose the greatest distance of the second spiral line of the volute from the outer spiral that from D to L, the distance from L to *r* may be divided into seven equal parts as a scale similar to A C. Set up, on the perpendicular line O D, half of one of these

sevenths, and you will have a point for finding the centres of the second spiral, corresponding with the point a of the first; from which proceed according to the directions laid down for the first. Spirals may be drawn from the points M N P in the same manner, dividing the different spaces M r, N r, P r, each into seven equal parts as a scale, and so on to any number of revolutions required. The lines connecting the opposite spirals of the volutes, are some straight, others curved; the straight lines of course can be drawn with a ruler; the curves must be drawn by hand: measure on a perpendicular line drawn through the centre of the column, the greatest distance one curve is from another; and from the terminations of the corresponding spirals, draw the curve lines through these points. Where great accuracy is required, perpendicular lines may be drawn at equal distances from either side of the middle perpendicular line, and the distance of one curve from the other at corresponding distances marked on them, through which the curves may be drawn,—as is shewn fig. 3.

Before commencing to draw an elevation of the Corinthian order, the distinguishing feature of which is the foliated capital, it is necessary to turn our attention a little to the drawing of foliage. Hitherto our progress has been easy, from all the lines and curves being determined by rule; much of ornamental drawing must however depend on the correctness of the eye and elegance of handling. Practice is the only way by which the student can expect to accomplish with beauty and facility this branch of drawing. He is recommended in the first instance to practise drawing curves of various kinds to be found in mouldings, volutes, &c. by means of points, commencing, in order to ensure correctness, with numerous points through which to draw the curve lines, and gradually diminishing their number, till his eye and hand become accustomed to their various forms.

The prototypes for drawing leaves, being found in nature, the student, after he has accustomed his eye and hand to execute a variety of geometrical curves, would do well to draw from nature the leaves and tendrils of various plants. The leaves surrounding a Corinthian capital, though similar in form, present a great variety to the eye, from the different angles at which they present themselves; those immediately in front of the column in an outline not shewing any projection, and those at the sides shewing the mere profile of the leaf and its greatest projection. In drawing an elevation where a number of columns are to be represented, it is necessary that they should be symmetrical, and the leaves of the same size and form; to perform this it is best to describe a right lined

figure about the leaf, intersecting various parts of the curves within it by straight lines, then constructing a similar rectilinear figure, find points corresponding with the intersections of the example, and draw the curves through these points, as the curves of ellipses, spirals, &c., have been described ; this will insure uniformity. Or the rectangular figure may be divided into compartments, which is perhaps preferable, as by this mode the form may be drawn to any proportion. Fig. 6, Plate V., is the representation of the profile of a leaf from a Corinthian capital, enclosed in a rectangular figure, giving its greatest height and projection, divided into sixteen compartments, figured from 1 to 16. The greater the number of compartments, the easier it will be found to draw the representation.

Let the student draw a parallelogram double the height and double the width of that in fig. 6, Plate V., and mark the different compartments from 1 to 16, as in the example; then mark the points on the several lines through which the outer curve of the leaf passes, corresponding with the points *a*, *a*, *a*, &c., fig. 6, and draw the line through them, endeavouring to keep one even, continuous sweep. It is best to hold the pencil at some length, and sketch the lines very lightly at first, going over and over the whole length of the line, till the contour is satisfactory ; then draw over the sketching lines firmly, one continued line, and rub out the sketching lines with bread. Take points from where to commence the principal parts of the leaf as at *b*, *b*, *b*, figs. 6 and 7, and other points *c*, *c*, *c*, to where the lines are to terminate and others again to commence, and draw the curves from point to point. Where certain portions may be more intricate than others, and great accuracy is required, the division containing them may be subdivided into any number required; practice enables the draughtsman to execute ornamental drawings with very few points; his eye gradually getting accustomed to the work, enables him to take distances with great accuracy without measurement. Only a small part of the leaf is represented in fig. 7, sufficient, however, to show the young draughtsman how to proceed with the remainder; to execute the long curves, let him mark the highest point first, with its greatest distance from that first drawn ; and then its lowest point and closest distance to the first drawn ; then draw the line, noting carefully its gradual diminution in distance from the other. Fig. 8 is the same leaf reversed ; supposing fig. 6 to be the outer leaf on the right of a capital, fig. 8, when finished, would represent a similar leaf on the left. By reversing the figuring of the compartments 1 to 16, as shewn in the figure, the drawing is accomplished as easily as that of fig. 7. The points *a*, *a*, *a*, in fig. 8, are marked

in the corresponding compartments to those of fig. 6; the highest point of one of the long curves, with its greatest distance from the outer curve, is marked at *d*, and its nearest distance at the point *e* and the line drawn through; several other points are also marked as directions for drawing the separate parts of the leaf.

Fig. 1, Plate VII., is a front representation of the same leaf of which we have given the profile, fig. 6, Pl. V.: one side is represented completed; the other divided into compartments, with portions only of the leaf drawn to enable the student better to understand the mode of proceeding. He is recommended to copy in this manner any good examples he can procure; and after completing one copy, to make another from it, as perfect a fac-simile of the first as possible; uniformity being one of the most essential parts of ornamental drawing.

Plate VI. contains an example of each of the four remaining orders of architecture; the Ionic and Corinthian both from the Greek models. After the copious remarks given in the preceding pages for drawing the example given Pl. IV., little remains to be said to enable the student to draw the examples before him; the directions given for drawing spirals, it is to be hoped, will enable him to draw the volutes; and those for drawing leaves, sufficient to insure uniformity in the representation of any number of them, an example of one leaf being given. Each specimen of an order is divided into its several divisions and subdivisions, and the dimensions marked against each. The mouldings vary in their arrangement; but as the name of each moulding, according to its form and the mode of describing the contour, has been given in the third Chapter, and illustrated in Plate II., they may be drawn without farther direction. The modillion, an ornamental bracket, is a feature in the cornice of the Corinthian order, not yet described; to give a representation of this requires no further directions, either for the front view or for the profile; an example of a modillion in profile is given at fig. 2, Pl. VII. The representation of modillions in an elevation is generally so small, that their size and position may be drawn by right lines, like the regulæ or mutules, and the form of the modillion drawn within the lines by eye; if of a large size and much enriched, the right lined figure containing the modillion may be divided into compartments similar to the profile of the leaf, fig. 6. Pl. V., marking the points through which the various lines pass.

For the advantage of representing the bases and capitals of the columns, as well as the several parts of the entablature, of as large a size as the limits of

our plates will permit, the whole length of the shaft is not drawn; the superior and inferior diameters, however, are both given, and the length of the shaft marked between them; the student can therefore find no difficulty in representing them in his drawing of their entire length.

The Doric, as we have before mentioned, is for the most part almost bare of ornament; the other orders, and more particularly those of the Roman style, are on the other hand occasionally highly enriched; to so great a pitch has the enrichment of some of the Roman orders been carried, that there are examples where scarcely a portion is to be found that is not covered with some kind of ornament. The friezes frequently contain series of figures, representing processions, &c., sometimes combinations of foliage and animals; the representation of these depends less on rule than on the correctness of the eye and hand. Much of the decorative part of both Grecian and Roman architecture consists of foliage; and though the representation of this depends mainly on skilful handling, still the division of the examples into small rectangular compartments will enable the draughtsman to represent the curves with tolerable accuracy, and preserve a uniformity in form and size. A common mode of ornamenting mouldings is by carving on them an ornament called the egg and arrow, or egg and tongue. Fig. 3, Plate VII., is an example of the egg and tongue ornament on a Grecian ovolo; upright lines are drawn at regular intervals to shew how the uniformity of the different parts may be preserved in a long series of these ornaments. Fig. 4, is an example of a Grecian cima recta, enriched with carvings of foliage. Fig. 5, an enriched cima recta of a Roman cornice. Fig. 6, an elegant ornament taken from the neck of a Grecian capital. These figures are intersected by lines, and similar lines are drawn at the sides to shew how they may be copied, and portions of each are commenced at various parts, always commencing with the principal curves. All these figures may be drawn as described for fig. 6, Plate V., and any other examples may be copied in the same manner.

There is a part not yet mentioned, belonging to an order placed upon the entablature, at the front or end of a temple, or over a portico, called the pediment. (Fig. 7, Plate VII.) The simple outline of a pediment, as is seen by the figure, is similar to the common gable end of a house, the angle formed by the junction of the oblique lines being generally more obtuse. The sides of a pediment are formed by a series of mouldings, sometimes similar to the cornice; the space contained in the triangle formed by the top of the entablature, and the sides of the pediment, is called the tympanum; this is commonly filled up with figures;

it is also very common to find ornaments or figures placed on the apex and at the sides of a pediment. The parts of a pediment are so similar to other parts of an order already described, that they may be drawn without further description.

The learner, desirous of exercising himself on the preceding information, may take as examples for practice the elevation of the principal front of the Athenæum Clubhouse,—Part I. in this Publication—drawing it to a larger scale; also the design for a verandah, with its different parts, represented in two Plates in the same Part, and other engravings interspersed throughout the Work.

The style of architecture commonly termed Gothic, the most fascinating to the eye of the painter, has so many varieties in the exquisitely beautiful arrangement of its parts, that it is quite impossible, in our small compass, to give examples that would convey even a limited idea of their beauties. The varieties of this style of architecture are arranged chronologically, and consist mainly in the form of the arches. In the earlier specimens the arches are semicircular; elevations of them can then be drawn by means of the compasses: from the semicircular, a change took place to the pointed arch, and the variation in the forms of these constitutes an essential point in the varieties of the pointed style. In the next portion of our subject, when treating of drawing arches in perspective, it will be necessary to shew how these arches are described in elevation drawing, before they can be put in perspective; we therefore defer this description till treating of arches in the following division, and will proceed at once to the leading principles of the second division of the subject on outline, Perspective.

CHAPTER V.

ON OUTLINE.

Perspective.

Before commencing the branch of drawing, termed perspective, it is necessary to comprehend what the term means; to understand well, before commencing operations, what is required to be done. Considerable difficulty is frequently experienced in making a young student in drawing thoroughly com-

prehend what is meant by perspective.* The positive form of the objects that daily and hourly come under our observation, is so strongly impressed on the mind, that it is not easy to reconcile ourselves to the idea, that in a correct representation of these objects in drawing, when they present themselves to the eye at an angle, the form in outline is never the same as the real form; nevertheless such is the fact.† In the perspective delineation of a square, which in its geometrical description has its opposite sides equal and all its angles right angles, the form completely changes; the sides are no longer equal, nor are the angles right angles; it assumes the form either of a trapezium or  trapezoid. The cube, which we know to have all its six sides  regular squares, assumes the form of an irregular hexagon. The circle instead of being represented by a curve line, equidistant in all its points from the centre,assumes the form of an ellipse, flatter or broader according to its  position above or below the eye of the spectator, or the angle at which it is viewed.

Let us endeavour, by examples, to explain to the student these apparent changes in the form of objects in their perspective delineation.

In the annexed woodcut the reader is to suppose himself looking out of a window at the objects visible from it; and it must be obvious to any one, even of the most ordinary capacity, that the representation here given is essentially correct; that although the opening through which the view is seen, the space occupied by the window, is an area of but a few feet, an extensive view is visible to the spectator through it, embracing a distance perhaps of many miles. It will be observed, that according to the distance of objects from the station of the spectator,—objects that are in reality of the same magnitude,—they vary in their apparent size; that the nearer any of these objects are to the spectator, the larger they appear, and the greater the distance so does their size apparently

* An elementary treatise on this subject, published by Mr. Weale, and addressed to amateurs and juvenile students in drawing, gives a very clear insight into the use and application of the rules of perspective; and would be found a useful introduction for any desirous of making acquaintance with this indispensable branch of drawing. The work is entitled "A Practical Treatise on Perspective, simplified for the use of Juvenile Students and Amateurs," by G. Pyne. 1846.

† The sphere is an exception; viewed from any point, its form is invariably the same.

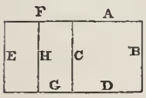
diminish. The flower-pot on the window-ledge, containing the plant, is in reality but a few inches in height, yet from its being so close to the spectator, it is represented higher than the figure of a man mounting a ladder by the side of the house opposite, though we know that man to be at least ten times the height of the flower-pot. Again, we see in the cut that a single pane of glass in the open window, which is quite close to the spectator, appears so large in proportion to the opposite building as would allow the whole corner of it to be seen through this single pane; and that an entire window of this building, though at so short a distance, occupies but a small space in the representation of the one single pane of glass so close to the eye. The plant in the flower-pot in the engraving is represented much larger than the tree overhanging the wall, though taking the average height of the figure to be between five and six feet, the tree must be really near twenty feet in height, though the plant is not so many inches; and a very large object, the barn on the right, still farther distant from the spectator, does not appear half the height of the flowerpot and geranium; the distant mountains, yet farther off, though probably of considerable altitude, are apparently not much higher than the thickness of the bottom rail of the window.

There are, in addition to the apparent decrease in the size of objects as they recede from the eye, other circumstances to be observed in perspective representations. In a careful examination of nature, or the objects intended to be represented, there is not only an obvious variation in their apparent size, but also constant variation in their form, and according as the distance is increased, the sharpness of the outline gradually decreases, arising from a less determined light and shadow; and a diminution of the intensity of their colour is also very perceptible. Perspective drawing is the art of representing objects as they appear to the eye. Linear perspective shews how to represent the various apparent changes in the size and form of objects, according to their distance, and the angle at which they are seen, by outline; the rules for drawing linear perspective are unerring, deduced from the science of optics, and capable of mathematical proof. Aerial perspective, is the art of representing the apparent distance of objects, by the force or delicacy of tone and color; to use the painter's expression, it is the representation of atmosphere; it depends upon taste, and careful investigation of the ever changing effects in nature, and constitutes one of the greatest excellencies of the painter. It is to linear perspective only that this portion of the work applies.

The student must perfectly understand first, that in perspective delineations

all objects decrease in size according to the distance from which they are viewed by the spectator; and secondly, that as well as diminishing in size, they also change their form. Let us refer to the wood engraving at the head of the chapter, and assuming the window through which the picture is seen, to be of the same size as those seen in the opposite building, the one on the shadowed side of the house, though represented so much smaller than that through which it is seen, is considerably larger than either of those on the side of the building in light, from its being nearer to the spectator; the nearest window on the light side of the building will be found to be larger than the farther one, and if a row of twenty windows were continued, they would gradually decrease in size as the distance from the spectator increased. The figure on the ladder is represented much larger than the one on the footway by the garden wall, from its position being so much nearer the eye ; and if we imagine a series of figures, like a line of soldiers, extending as far as the eye could reach, it must be obvious that they would gradually diminish till they became mere dots. Understanding then that objects represented in perspective decrease in size according to their distance from the spectator, it is not difficult to comprehend that their apparent form varies from their real form. The window seen on the shaded side of the house, though represented much smaller than that through which it is seen, does not change its form, and this because it is parallel to the window from which it is seen ; to express this more technically, the window is said to be in a plane parallel to the plane of delineation.* Not so with the windows on the light side of the house ; these, which are seen at an angle with the plane of delineation, no longer retain their original form of a rectangular parallelogram, but take that of a trapezoid, which varies according to its position. So with the top and bottom of the flower-pot and saucer, we know the form to be round or circular, or nearly so, but in their perspective delineation they assume somewhat the form of the ellipse.

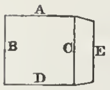
The great distinction between geometrical drawing and perspective drawing, consists in the manner of representing the parallel lines of objects ; in the former, geometrical drawing, parallel lines, if continued to any extent, would never meet; whereas in the latter, perspective drawing, in the *representation* of parallel lines, they always incline towards each other or converge, and if continued would meet in a point.



Let us suppose that we have a square box (a cube) placed before us in such a position as to see the front and one of the sides. Let A B C D

* This as well as some other planes will be explained in our progress.

represent the front of the box, and on the side C draw a square, C E F G, for the side; it must be quite clear that this cannot be correct, for where could we possibly draw the top, if that, as well as the front and side, were visible? One side of the top must join the line A of the front; another side of the top must join the line F of the side. We have shewn that objects of the same length appear smaller as they are removed from the spectator; the line E must necessarily then be represented shorter than the line C. The line H divides the square C E F G into two equal parts; the space therefore between H E being farther off than the space C H, must be represented narrower; so that the line E is represented less than the line C, and the space C E narrower than the space B C, as in the following diagram. Join the top and bottom of the line C with the top and bottom of the line E, and it will give a representation of a cube in perspective, of which two of the sides only are visible.



Let A B, fig. 1, Plate VIII., represent the nearer side of a window viewed at an angle: now as it has been already shewn that things of the same size are represented less and less according as they recede from the spectator, the side of the window farthest off must be shorter than the nearest; let C D then represent the length of the further side of the window. It is quite clear from this, that, in order to draw the top and bottom of the window by the lines from A to C and B to D, these lines must incline towards each other; and if these lines were continued they would meet in a point, as at E; the rule for finding the points to which the inclined lines of a perspective drawing tend, is the first and great object required, for without it we can do nothing. Let us take the front elevation, fig. 6, Plate I., and put it in perspective, drawing it to the same scale. We must suppose ourselves standing to the right of the cottage, in such a position as to see both the front and side elevations. Let A B, fig. 2, represent the line 8, 10, of the elevation, and C D* the line 1, 9, which being farther from the spectator than A B, must nccessarily be represented shorter; join A C and B D, and continue the lines till they meet at the point E; this point is called the vanishing point, and to this point all the parallel horizontal lines in the front elevation, fig. 6, Plate I., must be drawn in the perspective representation. Through this point, at right angles with the line A B, draw a line across the picture, and through the point B draw another line parallel to this last; that passing through

* The distance from C D to A B, and the height of C D, are assumed; the proper mode of finding the distance and height of C D will be explained as we proceed.

the point E is called the horizontal line, that passing through the line B the ground line.

The point F on A B represents the real height of the window from the ground, taken from the elevation, fig. 6, Plate I., and from F to the point G, the height of the window; but as the window is farther off than the angle of the cottage A B, the near side of it must be less than F G, and the further side less than the near side. If a line be drawn from the point G to the vanishing point E, and another line from the point F to the same vanishing point, it will intersect the line C D at the points H J, dividing the line C D into three parts, of the same proportions as the three parts of the line A B,* shewing the height the window would appear on the line C D, between the points H J. If any point on the line G J be taken, and from it a perpendicular line drawn to touch the line F H, it will give the length of the line F G at that particular point; we have therefore first to find at what point the nearest top corner of the first window will come on the line G J. From the point A, parallel to the horizontal line, draw a line the length of the front elevation A to K, and mark on it the distances of the windows from the sides of the cottage at 1 and 2, and the width of the windows at 3 and 4. The line A K, with the divisions on it, shews the geometrical proportions of the width of the parts of the elevation; the line A C is the perspective representation of the line A K, and we require a point by which we can obtain on A C the relative positions of the points 1, 2, 3, 4, on A K, as we have the relative positions of the points G F on the line C D. From the point K, through the point C, draw a line to touch the horizontal line at the point L; this will be the point required, or point of distance; from the point 1 to the point L draw a line intersecting the line A C at 5; from the point 2 draw a line to L, intersecting the line A C at 6; from the points 4 and 3 also draw lines to the point L, intersecting the line A C at 7 and 8; these points, 5, 6, 7, 8, are the perspective positions on the line A C of the points 1, 3, 4, 2, on the line A K. Between the lines G J and F H, perpendicularly under the several points 5, 6, 7, and 8, draw lines parallel to the sides of the cottage (A B and C D) which will give the representation of the apparent size and form of the windows in the elevation (fig. 6, Pl. I.), seen in perspective.

* To shew that the divisions on the line C D bear the same proportion to it as those on A B, a line is drawn from the point *a*, which divides the line A B into two equal parts, to the vanishing point, cutting the line C D at *b*, which will be found to divide the line C D also into two equal parts.

This mode of finding the point for ascertaining perspective distances is very satisfactory, and may be relied on for accuracy; it is particularly serviceable in drawing from nature, as it may be used with equal advantage for a part of a line as for the whole. For the satisfaction of the student as to the accuracy of this plan, let him refer to fig. 3, Plate VIII., which shews the perspective positions of the points 1, 3, 4, 2, at 5, 6, 7, 8, on A C, as found in fig. 2. G M (fig. 3) is also a perspective representation of the line A K. If the geometrical line were drawn from the point G to J, with its points of division 9, 10, 11, 12, G J will bear the same relative proportion to it that A C bears to A K; thus if a line be drawn from the point J through the point M, the point L, where it touches the horizontal line, will be the point of distance for finding the positions of the points 9, 10, 11, 12, on the line G M; as is seen by the intersections 13, 14, 15, 16, on this line by those drawn from the several points 9, 10, 11, 12, to the point of distance L; and the student will perceive that the several points 13, 14, 15, 16, lie perpendicularly under the points 5, 6, 7, 8; the point 13 under 5, 14 under 6, &c. The lines A C, G M, and B D, are each of them the perspective representation of the same length of line (A K), and the perspective positions of the sides of the windows may be set on either; so that had they been required on the line B D, the geometrical line must have been drawn from B to O, and the point of distance found by drawing a line from the point O through D to the horizontal line. Lines drawn from the points of division on B O to the point of distance L, will give intersections on the line B D perpendicularly under those on G M and A C.

This rule is particularly useful for dividing a perspective line into any number of equal parts. Suppose it is required to divide the line A C, fig. 4, into five parts; from the point A draw a horizontal line, and set off on it five equal parts from A to B; from B through C draw a line to the horizontal line at D, which is the point of distance, and to it from the points 1, 2, 3, 4, draw lines; the points of intersection on A C will give the required distances; but it is of no moment to what length the geometrical line is drawn, if the proportion of its parts is the same. Let A E represent the geometrical line, and *a*, *b*, *c*, *d*, the points of division; find the point of distance by drawing a line from E through C to F; if lines be drawn from each point of division *a*, *b*, *c*, *d*, to F, the intersections on A C will be in the same points as those drawn from the line A B to the point D.

To return to fig. 2: put up on the line A B, at M, the geometrical height of the door, and from it draw a line to the vanishing point E, which will give the perspective height of the door when the positions of its sides are found; to find these, measure on the line A K, from A, the distance of the nearest side of the door from the side of the cottage at 9, and from 9 the width of the door at 10, from each of which points draw a line to the point of distance L, and the intersections at 11, 12, on A C, will give the perspective positions of the points 9 and 10 on that line. Between the lines M E and B D draw lines parallel to the sides of the cottage, perpendicularly under the points 11 and 12, and the perspective outline of the door will be complete.

The line 2, 4, of the side elevation, fig. 7, Pl. I., being further from the spec-

tator than the line 1, 3, must be represented in fig. 2, Pl. VIII., like the line C D, shorter than the line A B. Let N O* represent the line 2, 4, of the elevation in perspective ; continue the lines A N and B O till they meet on the horizontal line at the point P, which point will form the vanishing point for all the horizontal lines of the side elevation. In order to draw the gable roof in perspective† we must first find the perpendicular line passing through the centre of the parallelogram of the elevation, fig. 7, Pl. I., here represented by the lines A, N, O, B. The centre of a rectangular parallelogram in perspective, is found in a precisely similar way to that of a geometrical one, by the intersection of its diagonal lines ; the intersection therefore of the lines A O and N B, at Q, is the centre through which to draw the perpendicular line Q R. Continue the line A B to S, the geometrical height of the gable, and from the point S draw a line to the vanishing point P ; where this line intersects the line Q R at T, is the perspective height of the gable ; draw the oblique lines T A and T N to complete the gable end of the side. From the point T, the top of the gable, draw a line to the vanishing point E ; this will give the perspective line of the top of the roof : there remains only, to complete this figure, a line from the point C, corresponding with the line A T ; this line C W is frequently drawn parallel to A T, which is incorrect. There are several ways by which the point W may be found ; as simple a mode as any is to draw a line from the point D to the vanishing point P, which line at that end of the cottage corresponds with the line B O of the end drawn ; from the point U draw a line to the vanishing point E, cutting the line D P at V ; from V draw a perpendicular line cutting the line T E at W, which is the point required ; join C W : the figure A T U B is the perspective representation of the half of the elevation, fig. 7, Plate I., and the figure C W V D is the same figure in a more distant position.

The Author trusts the student has been able to follow him in the foregoing description ; he has endeavoured to render the directions as simple as possible, keeping entirely to the practical part of his subject. Those who desire to acquire a theoretical knowledge of Perspective must consult more elaborate works ; but to understand them requires a considerable knowledge of mathematics, without which they are for the most part unintelligible. Trusting then that the fore-

* The height of this line, and its distance from A B, like the line C D, are assumed.

† The gable roof in this example is represented without any projections ; the introduction of them would create more intricacy than is judicious at so early a stage of our proceedings.

going is tolerably understood, we will make a few observations on the wood-cut at the commencement of this Chapter, before we proceed to the next.

It is easy to imagine a sheet of glass, or other transparent medium, placed between the spectator and the objects to be represented, on which the outline might be traced; suppose the woodcut to have lines drawn round it, to represent this, and on the surface of the glass you trace the outline of all the objects seen through it, the form of them must necessarily be such as they *appear* to the eye; this surface (which is in fact the picture) is called the plane of delineation, of which the base line is called the ground line. The point exactly opposite the eye of the spectator, is called the point of sight,* and a line drawn through this point, parallel to the ground line, is called the horizontal line.† It will be seen, in referring to the cut, that all lines parallel to the sides of the plane of delineation, that is, all the perpendicular lines of the real objects, are also perpendicular in the representation; that the horizontal lines on the shaded side of the building are all drawn parallel, and that the horizontal lines (that is, those lines that are horizontal in the object itself) on the light side of the building incline towards each other, and that if continued they would meet in a point. Fig. 5, Plate VIII., is a rough plan of the woodcut. Let A represent the position of the spectator, B C the opening of the window through which the view is seen, D E that side of the building in shade, D F the side of the building in light, and F G the garden wall; H J representing the base line of the plane of delineation.

It is necessary, in order to understand this diagram, fig. 5, that the learner should have some notion of how it is that we see objects. It is by means of rays of light passing from the objects themselves to the eye, and representing therein an image of the object; the rays always proceeding from the objects in straight lines and at every possible angle. Fig. 6 is a plan shewing the positions of three cubes, B, C, D, viewed from the point A; E F representing the ground line of the plane of delineation. The rays of light are sent from every point of every face of the cube in every possible direction. It must be evident from this figure, that none of the rays proceeding from the sides *b, c, d,*

* The point of sight in this representation is also the vanishing point; and let it be remembered that the point of sight is the vanishing point for all the lines of objects that are at right angles with the plane of delineation.

† All lines parallel to this line, or, which is the same, to the base line of the picture, are called horizontal lines; but the line which passes through the point of sight is the horizontal line, or line representing the horizon, and its height depends on the position of the eye of the spectator. Much of the pleasing effect of a perspective drawing depends on the height of the horizontal line.

of the cube C in this position, could ever come to the point A, and consequently that the side *a* would be the only side visible, and that a part only of the rays proceeding from the side *a* would arrive at A. Where the extreme lines representing the rays from the ends of the side *a* in their passage to the position of the spectator A, cross the plane of delineation at *e f*, they denote the length the line *a* should take in the picture. In the plan of the cube D, the rays from two of the sides, *a* and *d*, would arrive at the point A, causing both of these sides to be visible; and the rays from the extremities of the lines *a* and *d* would cross the line E F at *g*, *h*, *i*; *g h* denoting the width of the side *a* on the plane of delineation, and *h i* that of the side *d*. Precisely the same as with the rays from the cube D proceed those from the cube B, the right side of the cube being visible instead of the left. Let us suppose two other cubes placed behind the cube B, as G and H; it is obvious that the fronts of these cubes would not be visible, the cube B covering the cube G, and the cube G covering the cube H; but the inner sides of them would be visible, and lines drawn from their extremities to the point A would intersect the plane of delineation at the points *k*, *l*, *m*, *n*, demonstrating that as the cubes recede from the spectator, the representation of them on the plane of delineation diminishes. The width of the side of the nearest cube B, represented between *k* and *l*, on E F, is greater than that of the side of the second cube G, represented between *l* and *m*; and this again is greater than the side of the cube the farthest removed, represented between *m* and *n*.

Suppose the position of the spectator to be removed a little to the left at J, the same two sides of the cube D, *a* and *d*, are visible to the eye, but by different rays, and they do not consequently preserve the same relative proportion; from the position at A, the side *a* is represented considerably wider than the side *d*; from the position J, the two sides are represented much nearer the same size; if the position of the spectator were still farther removed to the left, the side *d* would appear the widest. From the position at J, the side *d* of cube C becomes visible, but the representation would be extremely narrow, as shewn by the intersections on the plane of delineation by the dotted lines.

To return to the plan, fig. 5; the lines from the points D E, the extreme points of the shaded side of the building that are visible through the opening for the window B C, are drawn to the point A, the position of the spectator, to shew the spaces they occupy on the plane of delineation; as also the lines representing the light side of the building, with the spaces for the windows and the length of the wall. It will be seen by the plan, that the line D E is parallel to the line H J representing the ground line of the plane of delineation; and as the face of the building stands perpendicularly over the line D E, the face of the building must be parallel to the plane of delineation. When the plane of any object is parallel to the plane of delineation, the horizontal lines do not tend to a vanishing point, but are parallel to the base of the plane of delineation; consequently the representations of the forms on all such planes do not change, they only vary in magnitude according to their distance from the spectator; thus the corner of the building is represented a right angle, and the windows, with their subdivisions

into panes, are all rectangular, preserving their real form, but represented of a smaller size. The side of the house, D F, being at an angle with the plane of delineation, all its horizontal lines must tend to a vanishing point; and standing at a right angle with the plane of delineation, the vanishing point will be in the point of sight E; the lines of the top and bottom of the wall also incline to the same point, as the wall is in the same plane as the side of the house. All the parts of the window through which the view is seen, as the sash, window ledge, side walls, &c., are either parallel to the plane of delineation, or at right angles with it; all the lines representing the several parts, therefore, parallel to this plane, are drawn parallel to the ground line, and all those representing the parts at right angles with it, incline to the vanishing point E. The difference of form in the representation of the flower pot and saucer from that of the circles denoting their position in the plan, must be obvious; but we must postpone the description of representing circles in perspective to another Chapter: all that is here intended is to make the reader understand that objects seen perspectively change their form and size; that the size diminishes according to the distance from the spectator; and that the size and form that objects appear to have may be regulated by drawing lines to certain fixed points.

CHAPTER VI.

Prop. 1.—To find the vanishing points for the delineation of a cube; the position of the cube B C D E, fig. 1, Plate IX., and the station A of the spectator, being given, F G representing the ground line of the plane of delineation.

From the point A, parallel to the side D E of the square, draw a line to intersect the line F G at H; and on the opposite side, from the point A parallel to the line E C, draw a line to intersect the line F G at J.

Construct a parallelogram, fig. 2, to represent the picture, (called the plane of dfelineation,) making the base line equal to the ground line of the plane of delineation F G, and mark on this line the points H and J; the points perpendicularly over these two points H and J, on the horizontal line, will be the vanishing points required. We must now determine the height of the horizontal line,

which is always regulated by the height of the spectator's eye from the ground plane.* Let us suppose that we are working on such a scale† that the base line of the picture represents a length of twenty feet; taking the height of the spectator's eye to be five feet from the ground plane, draw a line across the picture, five feet of the scale above the ground line, and parallel to it, which will represent the horizontal line; on this line, perpendicularly over the points H and J, mark the points *a* and *b*. The point *a* will be the vanishing point to which all lines in the original object (A B C D, fig. 1,) parallel to the line D E, will incline; the point *b* will be the vanishing point to which all the lines in the original object parallel to the line C E will incline.

Prop. 2.—From the figs. 1 and 2, to complete the perspective delineation of the cube.

Construct a parallelogram, similar to fig. 2, in which draw the horizontal line, and mark the vanishing points *a* and *b*; then on the plan fig. 1, from the points B D C E of the square, draw lines to the point A, to represent the visual rays of the extremities of each side of the square, intersecting the line F G at the points 1, 2, 3, 4; then will the distance from 1 to 3 represent the width to draw the side D E of the cube, and 2, 4, the width to draw its opposite side B C; 3, 4, denotes the width of the side C E, and 1, 2, the width of its opposite side B D. Continue the line D E till it meets the line F G at K. Mark all these points on the line F G, fig. 3, and you have all the points necessary to draw the perspective representation required.

From each of the points 1, 2, 3, 4, and K, on F G, fig. 2, draw up perpendicular lines. The point K is the continuation of the line D E to the line F G on the plan; draw then a line from the point K, fig. 2, to the vanishing point *a*, cutting the perpendicular line drawn from 3 at *c*, and the perpendicular line drawn from 1 at *d*; the line K *c d* represents the line K E D of the plan in perspective, and where it passes between the perpendicular lines drawn from

* The ground plane is in fact the ground on which the objects to be delineated stand, understood to be a horizontal plane. The whole space between the ground line of the picture and the horizontal line, represents the ground plane, on which are placed the various objects to be represented. All surfaces parallel to the ground plane are said to be in horizontal planes; all surfaces at right angles with it are said to be in vertical planes.

† It would have been equally easy to have drawn the whole of these figures to a scale giving the size of the cube, its distance from the plane of delineation, and the distance of the spectator from that; but not being essential to our present object, every thing not absolutely necessary to exemplify that portion of our subject immediately under consideration is avoided.

3 and 1, as from *c* to *d*, it represents the bottom line of the cube corresponding with the line E D of the plan; from the point *c* draw a line to the vanishing point *b*; where this crosses the perpendicular line drawn from 4 at *e* it represents the line E C of the plan; from the point *e* draw a line to the vanishing point *a*, cutting the line *d b* at *f*; the line *e f* corresponds with the line C B of the plan, and the line *d f* corresponds with the line D B; thus the geometrical square E D B C is represented in perspective by the figure *c d f e*, on which to construct the cube. On the line K *g* set up the height of the cube (the length of either side of the plan E D B C) at *g*, and from this point draw a line to the vanishing point *a*, cutting the perpendicular lines from 3 and 1 in the points *h* and *i*; *c h* represents the height of the angle of the cube over the point E, *d i* the angle over the point D. From each of the points *h* and *i* draw lines to the vanishing point *b*, where the line *h b* intersects the perpendicular line drawn from 4 at *k*; *e k* represents the angle of the cube standing over the point C; from the point *k* draw a line to the vanishing point *a*. Where the line *k a* intersects the line *i b* at *l*, *f l* represents the angle of the cube standing over the point B. This completes the drawing of a cube in perspective viewed from the position shewn in the geometrical plan fig. 1.

By reference to the plan, it will be seen that the angle over the point E is the nearest, consequently the line *c h*, representing this angle in the perspective drawing, is the longest; the point D being nearer to the spectator than the point C, the line *d i*, though less than *h c*, is longer than *k e*; the angle over the point B being farthest removed from the spectator, *f l* in the perspective drawing is the shortest of the four lines representing the four perpendicular angles: and the same will be observed of the lines representing the horizontal angles, the line *d c* (D E of the plan) is longer than the line *f e* (B C of the plan), and the line *i h*, the nearest horizontal angle at the top, is longer than the opposite angle *l k*; so also the lines representing the nearest horizontal angles *c e* and *h k* are longer than those representing the opposite angles *d f* and *i l*, demonstrating that objects of the same size, in their perspective representation, diminish as their distance increases from the station of the spectator.

In finding the points *l* and *f*, which determine the width of the two sides of the cube that are not seen, those between *k e* and *f l*, and *d i* and *f l*, they were found by the intersections of the lines *i b* and *k a* for the point *l*, and the lines *d b* and *e a* for the point *f*, not making use of the perpendicular line drawn from the point 2. But it will be observed, that these intersections come exactly on this perpendicular line; shewing that if a perspective drawing is executed with nicety you may arrive at the same result by different processes.

PROP. 3.—To find the vanishing point for the delineation of a cube, with its

sides parallel to, and at right angles with, the plane of delineation; and to draw the cube in perspective.

B D C E, fig. 3, represents the position of the square on which the cube stands, and A the position of the spectator; F G the ground line of the plane of delineation. Proceed first to find the vanishing point. It must be evident that in this position of the cube, the lines D E and B C being parallel to F G, no line drawn from the point A parallel to D E could ever intersect the line F G, as parallel lines produced to any length can never meet; the sides of the square D E and B C then can have no vanishing point, but must be drawn parallel to the ground line. The point J, the position of the vanishing point for the sides E C and D B, is perpendicularly over the point A, and is the point also denoting the point of sight; continue the line B D to the point K, and draw the visual rays from the angles of the square, as in fig. 1, to the point A. Mark all the points on F G in the plan, on F G, fig. 4, the ground line of the picture, from each of which draw perpendicular lines. Mark the vanishing point *b*, and to it draw a line from the point K; where this intersects the line drawn from 1, it gives the point *d*, marking the position in perspective of the point D of the plan, at its distance D K from the line F G: from the point *d* draw a horizontal line to meet the line drawn from 3 at *c*; *d c* represents the perspective length of the line D E, fig. 3. From the point *g*, (K *g* being the geometrical height of the cube), draw the line *g b*; the intersection of this with the line drawn from 1 at *i*, gives the length *d i* of that angle of the cube over the point D of the plan; a horizontal line from *i* meeting the line from 3 at *h*, represents the nearest upper horizontal angle; the line between *h c*, the angle standing over the point E; *d i h c* represents one of the planes of a cube parallel to the plane of delineation. Where the lines *g b* and K *b* intersect the line drawn from 2 at the points *l* and *f*, *l f* represents the angle of the cube standing over the point B. From the points *l* and *f* draw horizontal lines to meet the line from 4 at *k* and *e*; *f e* represents the line B C; and *l k* the opposite upper horizontal line to *i h*; *d f* represents the line D B; and *c e* the line E C; *i l* and *h k* the upper horizontal lines of the cube at right angles with the plane of delineation.

These two examples, figs. 2 and 4, elucidate the remarks made in the foregoing Chapter. In noticing the view from the window in the woodcut, we remarked that those windows represented on the shaded side of the house, though represented on a small scale, preserved their original rectangular form, because that front of the house was in a plane parallel to the plane of delineation. By the example given, figs. 3 and 4, it is shewn that this must be so, as whatever distance the horizontal lines

of objects in planes parallel to the plane of delineation may be removed from the station point of the spectator, they can have no vanishing point; thus the figure *d i h c* is as perfect a square as the original square of the cube D B C E, but smaller, from its distance from the ground line (K to D); and the figure *f l k e* is also a true square, but being still farther off, is represented smaller. It was also remarked, that where a plane was at an angle with the plane of delineation, the horizontal lines on it would incline towards each other, and meet in a point; if this angle was a right angle, the vanishing point would be in the point of sight. This is shewn in figs. 3 and 4, by the lines D B and C E, which being at right angles with the line F G, have their vanishing point in the point of sight.

If the angle of the plane of any object with the plane of delineation, be other than a right angle, then the vanishing point will be found on some other point of the horizontal line, as seen figs. 1 and 2. The point of sight is a point found perpendicularly above the point A, shewn on the horizontal line, fig. 2 at ⊙; all the sides of the cube being at an angle with the plane of delineation, and neither of them at a right angle, their vanishing points come on points removed from the point of sight; therefore we may state as fundamental rules, that

All Horizontal lines in a plane parallel to the plane of delineation, in a perspective drawing, are parallel to the ground line of the picture.

All Horizontal lines in a vertical plane at right angles with the plane of delineation in a perspective drawing, incline towards a point in the horizontal line, opposite the eye of the spectator, called the point of sight.

All Horizontal lines in a vertical plane at any angle with the plane of delineation, not a right angle, in a perspective drawing, incline towards a point in the horizontal line, either to the right or left of the point of sight, called the vanishing point.

CHAPTER VII.

Before proceeding farther, let us here strongly impress on the mind of the student the necessity for his exercising assiduity and patience; bearing ever in mind, "that nothing is denied to well-directed labour." Let him not be discouraged if he does not thoroughly comprehend what he has read up to this point; but if such should be the case, recommence from the beginning of this part of the subject, (Perspective,) page 36, give it a patient perusal, carefully drawing the different figures on a larger scale; let him draw, line by line, each figure according to description, and he will find that what at first may have appeared confused and obscure, will become clear and satisfactory. After

drawing the examples given, Plate IX., let him draw a variety of cubes, changing their positions with reference to the plane of delineation, till he feels himself capable of drawing a cube in perspective in any position in which it may be placed ; he will then have become practically acquainted with the broad leading principles of perspective—for upon these rules, as a groundwork, he may proceed to put into perspective the whole face of a building.

Fig. 3, Plate X., represents the perspective representation of a desk, a portfolio, and a rule, lying on a square table, of which fig. 1 is the plan. B C D E represents the surface of the table; A the position of the spectator ; and F G the ground line of the plane of delineation.

Prop. 4.—From the above plan to find the perspective positions of the objects.

Proceed as in figs. 3 and 4, Plate IX., to put the square representing the table in perspective, as shewn at *c d e f*, fig. 4 ;—observing that the vanishing point (perpendicularly over the station point A) is between the two sides of the square, instead of being on one side. Having constructed this figure, (B C D E, fig. 2), draw with ink the lines representing the picture F G J K, the horizontal line, and the square in perspective B C D E, and rub out all the pencil lines used from the plan to put the square in perspective, represented in the plate by dotted lines.* Let *a b c d*, fig. 1, represent the form and position of a writing-desk standing on the table. To avoid any confusion with what has been previously done, let the student imagine this oblong figure to be the only figure to be represented in perspective, without reference to the square table. Let F G represent as before the plane of delineation ; and A the station point of the spectator ; F G J K the picture on which it is to be drawn. Draw the figure precisely in the same manner as the last, observing that as the side *a d* is in a direct line with the spectator's eye, the points *a* and *d* will come on the same point on the line F G, and that will be on the point representing the point of sight; consequently that side will be represented by a perpendicular line. Draw the lines *a b c d*, fig. 2, in ink, and as before rub out all the pencil lines that have been used from the plan, so as to be enabled to proceed with the next figure without any confusion from the lines necessarily used for the preceding ones. The table and desk

* The multiplicity of lines perplexes, and almost alarms many students ; but it must be evident, that in our examples we are compelled to leave every line that has been used to produce the various figures ; the student, however, can rub out his pencil lines on the completion of each part of his drawing ; by this proceeding each individual part of this figure becomes a separate problem.

are both of them represented to stand parallel to the plane of delineation, consequently the vanishing point for the sides is found in the point of sight; but the next figure, *e f g h*, which represents the form and position of a portfolio lying on the table, is at an angle with the plane of delineation; the vanishing points must therefore be found away from the point of sight. To accomplish this, the vanishing points L, M, of the figure *e f g h*, must be found in the same manner as H and J, those for the figure B C D E, fig. 1, Plate IX.; and the position and form of the portfolio drawn in a similar manner to the figure *c d e f*, fig. 2, Plate IX. Draw the figure in ink, and rub out the pencil lines. The figure *i k l m*, representing the form and position of a flat rule, also lies at an angle with the plane of delineation, but not parallel with the last figure drawn; other vanishing points, N, P, therefore must be found as in fig. 1, Plate IX.; and proceed to draw this figure precisely in the same way as the last. This will complete the plan in perspective of the table, desk, portfolio, and rule, of the geometrical plan, fig. 1.

If the height of the desk, the thickness of the sides of the portfolio, and of the rule, were given, the mode for completing the drawing of the figures is in every respect the same as that given for the completion of the figures of the cubes, figs. 2 and 4, Plate IX. These additional parts are only omitted in this figure, to avoid the confusion that would unavoidably arise in the number of lines requisite for this purpose; but fig. 3 is a representation of the same objects from a similar station, drawn to double the scale.

The student will observe in this figure, that the table and desk, being parallel to the plane of delineation, have their vanishing points for the sides at right angles with it in the point of sight, as would any number of objects similarly situated; that the portfolio and rule being at an angle other than a right angle with the plane of delineation, have their vanishing points away from the point of sight; and that from their lying at different angles with the plane of delineation, their vanishing points also are different. If twenty portfolios were piled one upon another, so as to lie evenly with the edges of one immediately over the edges of another, the lines of the sides would all be drawn to the same vanishing points; but if they were laid unevenly, so that the side of one portfolio was at an angle with the side of another, each portfolio must have its distinct vanishing points. The corner point of the portfolio *e*, on the plan, is purposely placed exactly at the edge of the table, in order to shew the accuracy with which the relative positions of the points are preserved between the perspective and geometrical drawings—the same corner of the portfolio *e* coming exactly at the edge of the table in the perspective drawing.

The foregoing subject, Plate X., has been chosen as a familiar example to shew how, from a plan, a variety of objects in different planes may be put in

perspective; but whether the objects to be represented are, as in the example, a table or a book, &c., or the different parts of the ground plan of a building, the mode for finding the points for the perspective representation is precisely the same as for those figures given in the preceding examples. The figures hitherto chosen are simple parallelograms, but the directions given for drawing them are sufficient to enable the student to put any right-lined figure into perspective.

Prop. 5.—From the plan B C D E F G, fig. 5, Plate IX., the plan of a hexagon viewed from the point A, K L representing the ground line of the plane of delineation, to draw the perspective form and position.

From each of the points B, C, D, E, F, G, draw the visual rays to the station point A, intersecting the line K L at the points 1, 2, 3, 4, 5, 6. The sides B C and E F being parallel to the plane of delineation, will have no vanishing point, but must be represented by horizontal lines; the vanishing points for the lines at an angle with the plane of delineation, are found as in the preceding examples. B G and D E being parallel, will have the same vanishing point at H, and C D and G F being parallel, will have the same vanishing point at J. Mark all the points described on K L, fig. 5, on the ground line fig. 6, and raise perpendicular lines from each point, marking the point of sight ʘ and the vanishing points H and J on the horizontal line. B C and F E being parallel to the plane of delineation, their width may be determined by lines drawn to the point of sight. From the point B of the plan draw a perpendicular line to the line K L at *a*, and place the point *a* on the ground line, fig. 6, from which point rule a line to the point of sight ⊙, then *a* B, fig. 6, will represent in perspective *a* B, fig. 5, of the geometrical plan; from the point B draw a horizontal line to meet the line 2 at C, the distance between 1 and 2 representing the perspective width of the side B C. From the point B draw a line to the vanishing point H, till it meets the line 6 at G, the distance between 1 and 6 being the perspective width of the side B G of the hexagon; from the point G draw a line to the vanishing point J, till it meets the line 5 at the point F, from 5 to 6 representing the perspective width of the side G F. On the opposite side draw, in like manner, the lines C D and D E, and join the points E and F; the line uniting them will be found exactly parallel to the line B C, and the whole figure will be the representation of the hexagon, fig. 5, in perspective.

Here it will be well to remark that this figure is an excellent example to shew that the same

result may be arrived at, from whatever point we may commence. Had we commenced from the point B to draw the line B G instead of the line B C, G B in the geometrical drawing must have been continued till it met the line K L at *b*, and the point *b* marked on the ground line fig. 6, from which point a line drawn to the vanishing point H would have intersected the line 1 in the same point B as the line drawn from the point *a* to the point of sight ⊙. So with the point F. The dotted line B F, fig. 6, represents the dotted line B F, fig. 5, and the line *a* B F, fig. 6, intersects the line 5 in the same point as the line drawn from the point G to the vanishing point J. If it had been requisite to commence the perspective figure with the line G F, the line G F of fig. 5 should have been continued to meet the line K L at *c*, the point *c* placed on the ground line fig. 6, and a line ruled from it to the vanishing point J, as shewn by the dotted line *c* G which cuts the lines 6 and 5 in the same points G and F that were found by the previous method.

To construct, on such a plan as fig. 6, a solid figure, we should proceed in the same way as described for constructing the cubes; construct a square or oblong on the line B C, and from the upper line draw the hexagon in the same way exactly as that from the lower line. Fig. 7 represents a solid hexagonal figure constructed on the foregoing plan.

If the plane of delineation were such as is shewn by the dotted lines N P, every side of the hexagon being at an angle (not a right angle) with the plane of delineation, would have its vanishing point away from the point of sight; the opposite sides of a hexagon being parallel, three vanishing points would be required.

Any other rectilinear figure, either a triangle or polygon, may be drawn from these directions; the student is recommended to draw according to the foregoing description a pentagon, heptagon, and nonagon.

CHAPTER VIII.

Trusting that the matter in the foregoing Chapters has been sufficiently explicit to enable the student to comprehend the drawing of the various figures of which it is descriptive, we will proceed to put into perspective some figures

of common objects; premising that what we are about to perform depends entirely on the rules previously given, but that in executing the figures, those lines only will be used which are absolutely requisite for the object in hand.

Prop. 6.—From fig. 1, the plan, and fig. 2, Plate XI., the elevation of a square slab standing on two steps, viewed from the point A, to draw the perspective representation, B C marking the plane of delineation.

This figure, for the purpose of shewing the student how any object may be represented in perspective from measurement, is drawn to a scale of one-eighth of an inch to a foot in the plan and elevation; the perspective drawing, for the advantage of more clearly shewing the various points and lines, is drawn to a scale of a quarter of an inch to a foot. Let the student first, as in figs. 1 and 2, Plate IX., find the vanishing points for the sides *a b* and *c d* at E,* and for the sides *a c* and *b d* at D; then draw the visual rays of the four angles of the outer square to the station point, and continue the line *b a* to the line B C; mark all the points of intersection on the ground line of the plane of delineation 1 2 3 4 5, and the positions of the vanishing points E D, on the ground line of the picture, fig. 3, and as in the preceding figures draw the perspective square *a b c d*. The only use of the point *d* in this figure, is for drawing in perspective the diagonal lines *a d* and *b c*, which will be found of great value. From the point 5 set up a perpendicular line to serve as a line of projection for the measurement of the heights of the steps, and on it mark the height of the first step† at 6, from which draw a line to the vanishing point E; where it crosses the lines 1 and 2 at *e* and *f*, it gives the perspective drawing of one side of the lowest step, corresponding with the side *a b e f* of fig. 2. From the point *e* draw a line towards the vanishing point D till it meets the line 3 at *s*, which will complete the drawing of the other side of the lower step. Continue the lines 7 and 8 of the plan to the line *a b*, and from their points of contact draw visual rays to the station point, and carry the points of intersection, 9, 10, to the ground line of the picture; from the point 9 draw a perpendicular line intersecting *a b* at *g*, and *e f* at *h*; then *a e g h* will represent in perspective the square *a e g h* of the elevation. From the point *g*

* This vanishing point is found nearly at the extremity of our Plate; consequently the vanishing point for our perspective drawing must be some distance beyond our limits. The lines however are all drawn towards the letter E, and if continued would be found to meet in a point at its correct position on the horizontal line.

† Bear in mind that throughout this figure the measurements for the perspective representation are double the measurements of the plan and elevation; the student, however, as he will not be cramped for room, can draw the plan, elevation, and perspective drawing to the same scale.

draw a line to the vanishing point D; this will give *i*, a point on the diagonal *a d* corresponding with the point *i* of the plan, and *l* a point on the diagonal *b c* corresponding with the point *l* of the plan. From the point *i* draw a line to the vanishing point E; this will give *k*, a point on the diagonal *b c* corresponding with the point *k* of the plan.

Observe here that the width from *a e* to *g h* is found by means of the visual ray drawn from *g* to A and its point of intersection on B C carried to the ground line of the picture; 1, 9, representing the perspective width of *a g* of the plan; each of the corresponding points of the corners of the inner square could have been found in the same manner, but the process here taken is equally correct and far more simple. If the point marked *m* in the plan had been required, the intersections of two lines drawn from *k* and *l* to the vanishing points D and E would give this point, and would fall on the diagonal line *a d*; this point however is not required in this representation.

From each of the points *i*, *k*, and *l*, draw a perpendicular line; from the point *h* a line drawn to the vanishing point D where it crosses the perpendicular lines drawn from *i* and *l*, will represent the bottom line *n o* of the second step; from the point *n* a line drawn to the vanishing point E at its intersection with the perpendicular line drawn from *k*, will represent the bottom line of the second step on the other side. On the perpendicular line drawn from 5, set up the height of the top of the second step at 11, and from it rule a line to the vanishing point E; where this line crosses the perpendicular line drawn from the point 9 at *p*, it gives the point for determining the height of the second step in perspective; from *p* draw a line to the vanishing point D; where this intersects the perpendicular line drawn from *i* at *q*, it denotes the nearest top corner of the square; where it intersects the perpendicular drawn from *l* at *r*, it denotes the farthest top corner on the right; from the point *q* a line must be drawn to the vanishing point E; where this line intersects the perpendicular drawn from *k* at *t*, it denotes the further top corner on the left.

Proceed to draw the square slab on the top exactly in the same manner as the slab forming the second step. From the point 10 draw up a perpendicular line; from its point of intersection on *a b* draw a line to the vanishing point D; this will give the points on the diagonal lines over which stand the angles of the right side of the square; from the point of intersection on the diagonal *a d* draw a line to the vanishing point E; this will give a point on the diagonal line *b c* over which stands the angle to the left; from each of these points on the diagonal lines draw a perpendicular line. From the point in which the line drawn from 11 (the geometrical height of the bottom of the slab) to the vanishing point E,

intersects the perpendicular line drawn from 10 at *u*, a line must be drawn to the vanishing point D; where this line intersects the perpendicular lines drawn to represent the right-hand angles at *v* and *w*, it denotes the lower right-hand line of the slab; from the point of intersection with the nearest perpendicular at *v*, a line must be drawn to the vanishing point E; where it meets the perpendicular line drawn to represent the left-hand angle of the slab, it represents the bottom line on the left. To get the height of the top of the slab in perspective, set the geometrical height on the perpendicular line of projection 5 6 11, at 12, and from this draw a line to the vanishing point E; where this line intersects the perpendicular line drawn from 10 at *x*, it denotes the point from which to draw the upper lines of the slab; draw from *x* a line to the vanishing point D, and its intersections with the lines denoting the upright angles of the square at *y* and *z* will complete the right-hand side of the slab; from the nearest point of intersection, *y*, draw a line to the vanishing point E, which, where it meets the upright line of the left angle, will complete the drawing of the left side of the slab. From the corner *f* draw a line to the vanishing point D, to meet the angle of the second step; from the point *t* to the same vanishing point, draw a line to meet the angle of the upper slab. From the point *s* draw a line to the vanishing point E, to meet the angle of the step above, and from the point *r* to the same vanishing point a line to meet the angle of the upper slab; from the points *z* and its opposite angle draw lines to the respective vanishing points E and D, intersecting at the point F, and the perspective figure is completed.

In the examples hitherto made use of, the objects have been represented below the eye of the spectator; let us take an example where part of the object is below and part above the eye. The mode of drawing such a figure is the same as before described; but it will be seen, in our progress, that where any projection occurs in any object above the eye, it hides a part of the object above it.

Prop. 7.—From the given plan and elevation of an obelisk, with the station point and plane of delineation, to draw the perspective representation.

The plan, fig. 1, Plate XII., is figured to correspond with the elevation, fig. 2; 1, 2, representing the square of the base; 3, 4, the square of the coping; 5, 6, the square of the plinth, &c.; 11, 12, the inclined lines of the pyramid; and 13, the apex.

Proceed as in the last figure to put the plan into perspective, getting all the

points in it from 1 to 13. Set up the line A B as a line of projection for the perspective heights of the various parts. From the point A set up the height of the base at *b*, and draw the base as in the foregoing example.*

Note here, that to get the heights of the parts of the elevation in the perspective representation, it is required to find them first on perpendicular lines drawn from the line 1 to 14, by means of lines drawn from the geometrical measurements on A B, and carried from the points of intersection by horizontal lines to the perpendiculars drawn from the plan; thus to find the point of the apex at the top of the pyramid in the elevation, which stands perpendicularly over the centre of the squares at 13, both in the plan and perspective representation, a perpendicular line must be drawn from the point 13; somewhere on this line must come the point *f*. From the point 13 draw a horizontal line to meet the line 1 14; and from the point of intersection draw up another perpendicular line; from the point *f* on A B (the geometrical height of the apex) draw a line to the vanishing point; where this intersects the last perpendicular drawn from the line 1 14, it denotes the perspective height of the apex; and a horizontal line drawn from it, intersecting the perpendicular drawn from 13 at *f*, is the perspective position of the apex of the obelisk.

From the points 5 and 6 draw perpendicular lines to represent the sides 5, 6, of the elevation; continue the line 6 5, to 15, from which point draw a perpendicular line; from *c* on A B draw a line to the vanishing point; where this intersects the line drawn from 15, is the perspective height of *a c*; draw from this point a horizontal line; and where it passes between the perpendicular lines drawn from 5 and 6 it represents the line *c* of the elevation; how to draw the base line of this, shewing where it stands on the bottom slab, has been shewn in the preceding figure. From the points 3 and 4 raise perpendicular lines to represent the sides 3, 4, of the projection in the elevation; continue the line 4, 3, to the line 1, 14, at 16, and find the perspective representation of the parallelogram of the elevation from it (16) and the points *c* and *d* on A B as before directed, in this and the preceding problems, for similar figures. From the points 7, 8, draw perpendicular lines to find the perspective positions of the points 7, 8, of the elevation, from which the base of the shaft springs; continue the line 8, 7, to the line 1, 14, from the point of meeting draw a perpendicular to meet the line drawn from *d* to the vanishing point, from whence draw a horizontal line, cutting the lines drawn from 7 and 8 at 17 and 18, which are the points required. Here we see that the

* One side of the object being parallel to the plane of delineation, and the figure being rectangular, the vanishing point is in the point of sight.

line *d* of the elevation, in the perspective representation, hides the base of the shaft; nevertheless it is necessary these points should be found, as without them we should not be able to draw the perspective representation of the lines 7, 9; 8, 10. Draw perpendicular lines from the points 9, 10, and continue the line 10, 9 to the line 1, 14; from its point of contact draw a perpendicular line to meet a line drawn from *e* to the vanishing point, and from the point of intersection draw a horizontal line, cutting the perpendiculars from 9 and 10 in the points 19, 20; join 17 and 19, and 18 and 20, and we have the figure 7, 8, 9, 10, of the elevation in perspective. We have already shewn how to find the apex *f* in perspective; join 19 *f* and 20 *f*, and we have the whole figure of the elevation in perspective.

Let us here remark, that the plan of this figure is represented parallel to the plane of delineation, and that the individual parts, as *a b* 1 2, 5 6 *b c*, and 3 4 *c d* of the elevation, retain in the perspective representation their original form, because they are parallel to the plane of delineation; but the figure 7 8 9 10, and the figure 9 10 *f*, are neither of them parallel to the plane of delineation, and consequently do not retain their original form; the perspective figure 17 18 19 20, being a different form to the elevation 7 8 9 10, which it represents; also the perspective figure 19 20 *f*, is different to the figure 9 10 *f* of the elevation.

The rules for drawing the right-hand side of this figure have been so fully explained in the preceding figures, that it is needless to recapitulate them; the heights of all the further corners are regulated by lines drawn from the near corners to the vanishing point; the width of every part by lines drawn from the points of intersection on the diagonal line.

The whole of the foregoing figure, which may appear somewhat intricate to the young student, may be clearly understood by the diagrams, figs. 4, 5, 6, Pl. XI. Fig. 4 and fig. 5 represent the plan and elevation of a double cross, each forming a similar figure. Put the plan in perspective similar to A, fig. 6, and the elevation similar to B, fig. 6. From each of the points 1 to 12, (A, fig. 6,) draw a perpendicular line, and from the points *a* to *m*, (B, fig. 6,) draw horizontal lines, crossing the perpendicular lines drawn from A, fig. 6. The intersections of these lines will give all the points required for drawing this figure in perspective. The horizontal lines from *g h*, crossing the perpendicular lines from 1, 2, will give the nearest square of the cross 13, 14, 15, 16. The horizontal lines from *i k*, crossing the perpendicular lines from 10, 11, will give the square behind it, 17, 18, 19, 20; if the points 15 and 19, 16 and 20, and 14 and 18, are joined, it will complete the perspective of a solid cube, the nearest of the seven cubic solids forming the figure; and if these lines were continued on, they would meet in a point, the vanishing point used for putting the plan and elevation in perspective; the same will be found in every cube of which this figure is composed. So with the last figure; if we had put the ground plan in perspective, and by the side of it the elevation, perpendicular lines drawn

from all the points of the former, and horizontal lines drawn from all the points of the latter, would have given, by their intersections, all the points requisite for the perspective representation. This is really the process by which the preceding figure has been drawn, as may be seen by the dotted lines representing one half of the figure; half of the figure only being required to draw the perspective representation.

CHAPTER IX.

Having given thus much information, sufficient to enable the student to draw almost any rectilinear figure in perspective, we will now proceed to give directions for drawing curves. The only means by which curvilinear figures can be represented in perspective is by intersecting the curves by straight lines, putting those straight lines in perspective, and thus finding the positions of their intersecting points in perspective, through which the curves must be drawn.

In looking at any round object, as a plate, waiter, &c., unless we were to stoop over it, or that it were set upright, so as to bring the centre immediately opposite the eye, it would not appear to us a circle. Let us imagine a circular card, dark on the upper side and white beneath, with a perpendicular string or wire, from the ceiling to the floor, passing through its centre. If this card were slid up the string, above the eye of the spectator, he would lose sight of the black side, and the white would become visible; if it were slid on the string so as to come exactly even with the eye, neither side would be visible, but the thickness only of the card would be seen. The student can readily comprehend that in the gradual progress of the card from the ground to a position even with the eye, it must be constantly changing its form; the diameter one way always remaining the same, but the diameter the other way constantly decreasing till it becomes perfectly invisible. Fig. 1 represents this; the card at the position *a*, the lowest, shews the broadest figure and the dark side; at the position *b*, higher up, the dark side is still visible, but much narrower; at *c*, being exactly even with the eye, neither side is visible; at *d*, above the eye, the white under side becomes visible. To put a circle in perspective, we must first strike a circle with the compasses, and construct about it a square, as in fig. 2, Plate XIII.,

draw the diameters 1, 5, and 3, 7, and the diagonal lines intersecting the curve of the circle in the points 2, 4, 6, 8 ; and draw perpendicular lines through the points 4, 6, and 2, 8, to meet the opposite sides of the square.

Prop. 8.—From the diagram, fig. 2, to put the circle in perspective.

From the preceding examples the student ought to be able to put this rectilinear figure in perspective without assistance ; but the Author, from long experience in teaching, being aware that the most trifling variation will sometimes confuse the pupil, will proceed with the directions for this figure; giving the student to understand that the directions for drawing it will serve for any figure representing a circle or part of a circle in perspective.

In giving instructions for drawing this figure, it is unnecessary to go over all the ground we have trodden before ; let us hope that this square could be put in perspective from any given station-point ; we will therefore consider the figure A B C D, fig. 3, to be drawn so as to represent the square A B C D, fig. 2, in perspective. In the perspective square draw the diagonal lines A C and B D; carry the points E 3 and F, fig. 2, to the ground line, fig. 3, and draw from each point a line to the vanishing point. Where the line drawn from E intersects the diagonal A C, it gives a point corresponding with the point 2 of fig. 2 ; where it intersects the diagonal B D, it gives a point corresponding with the point 8, fig. 2. Where the line drawn from F intersects the diagonal B D, it gives a point corresponding with the point 4, fig. 2; where it intersects the diagonal A C, it gives a point corresponding with the point 6, fig. 2. The line drawn from 3 to the vanishing point, where it intersects the line C D, gives a point corresponding with the point 7, fig. 2 ; a horizontal line drawn through the centre of the perspective square (shewn by the intersection of the diagonal lines) will give a point on the line A D corresponding with the point 1, fig. 2, and on B C a point corresponding with the point 5, fig. 2. Thus we have the perspective positions of all the points 1, 2, 3, 4, 5, 6, 7, and 8 ; through which points if a curve line be drawn, it gives the representation of a circle in perspective, seen in a horizontal position.

If it were required to make a vertical representation of a circle in perspective, the process would be the same. Set up perpendicularly over the point A the line A *b*, from which draw the perspective square A *b* *c* D ; draw, as in the former figure, the diagonals A *c* and *b* D ; mark on the line A *b* the divisions *e* 3 *f*, rule a line from each to the vanishing point, and draw a perpendicular line through

the perspective centre of the square; the intersections of these lines will give in this figure all the points corresponding with the points 1, 2, 3, 4, 5, 6, 7, 8, of the preceding, through which the curve may be drawn to represent a circle in perspective seen in a vertical position.

Prop. 9.—To draw the perspective representation of the shaft of a column, the superior and inferior diameters of which are equal.

It is unnecessary in these problems, which are given merely as examples for drawing the representations of certain forms in perspective, to give a plan for each individual figure; it would be a waste of space and time. Any one of the plans in the preceding figures representing a square, seen from a stated position, may be supposed to contain a circle, and from it the student can make his drawing according to rule. In the following figures it is assumed that all the preliminary steps are gone through, and the points from which the representation of the square was drawn had been previously found.

Let A B, fig. 4, represent the diameter of the circle; from the point 3 describe the half circle,* from which, as in the preceding figures, find the points E and F. From these points, A, E, 3, F, B, construct a square, with the intersecting lines, marking the points to correspond with the last figure. At the proposed height of the shaft draw a horizontal line, and mark on it perpendicularly over the corresponding points on the ground line A, E, 3, F, B. From the points A and B draw lines to the vanishing point ⊙. Draw up perpendicular lines from the points D and C, and join their points of intersection with the lines A ⊙, and B ⊙, at C D. This upper figure, A B C D, represents a square in perspective, the sides and angles of which are perpendicularly over the sides and angles of the lower square A B C D. Draw the diagonal lines in the upper square, lines from the points E 3 F to the vanishing point, and a horizontal line through the centre, and you will have points of intersection corresponding with the points 1, 2, 3, 4, 5, 6, 7, 8, of the lower figure; the point 1 of the upper figure being perpendicularly over the point 1 of the lower figure, 2 over 2, 3 over 3, &c. &c.; draw the curve to represent the circle in perspective through the respective points in each figure, and join the side extremities of the top and bottom curves; this will complete the perspective representation that was required.

In the directions for drawing the orders of architecture, it was shewn that the

* It is needless to draw more lines than are necessary; the half circle being quite sufficient for the purpose required.

shafts of columns taper from the base upwards; we must therefore shew how such a column is to be represented in perspective.

Prop. 10.—To draw the perspective representation of the shaft of a column, the superior diameter of which is less than the inferior diameter.

Let A B, fig. 5, represent the inferior diameter of the shaft; draw the perspective square A B C D, in which construct a similar figure to the last drawn, and describe the curve; at the proposed height of the shaft draw a horizontal line, and set on it the points A B perpendicularly over the points A B on the ground line; from the points A and B draw lines to the vanishing point, and, as in the last figure, draw the upper perspective square A B C D, and within it the diagonal lines A C, B D. Let *a b*, on the ground line, represent the superior diameter of the shaft; from the centre *c* draw the geometrical figure, for which, observe, the same diagonals serve; find the points *d* and *e*, and mark between A and B on the upper line the several points *a*, *d*, *c*, *e*, *b*, perpendicularly over the points *a*, *d*, *c*, *e*, *b* on the ground line. From each of these points draw a line to the vanishing point; then *f g h i* will represent the square in perspective, in which the curve is to be drawn. Draw a horizontal line through the centre, and you will have intersecting points in the square corresponding with the intersecting points in the preceding figures, through which draw the curve; join the extremities of the upper and lower curves, and the figure required is completed.

Prop. 11.—To draw the perspective representation of a bridge with two semicircular arches, of which fig. 6 is the elevation on a small scale.

First construct a parallelogram in perspective to represent *a b c d*, fig. 6, as in fig. 7, which is drawn to double the scale of the elevation; and here we will make use of a rule by which we shall find the width of the piers and arches, and the points through which to draw the curves, by a shorter process than finding them from a plan. Let us suppose the perspective parallelogram to have been drawn from a regular plan; measure off on the ground line to the right of the point *a* the geometrical width of the piers and arches from *a* to *e* (double the length of the elevation, fig. 6); from *e* through *c* rule a line till it meets the horizontal line at *f*; this point will give the perspective distances on the line *a c* of any geometrical distance measured on the line *a e*,* as correctly as if they were drawn from the plan. Mark then in the spaces for the arches on *a e*, the points (1, 2, 3, 4, 5) required to draw the perspective curve, and carry these points to

* See Plate VIII., and Chap. I., on Perspective.

the line *a c* by means of intersecting lines drawn to the point of distance *f*; from each of these points draw a perpendicular line to meet a line from *g*, the geometrical height of the arches; from the middle point on *a e*, to each of the corners on the line drawn from *g*, draw a straight line, and you will have the inverted rectilinear figure below the line *a e* set upright in perspective in its correct situation on the line *a c*. We now require to draw the thickness of the arches, and to facilitate the student we have shewn the mode for accomplishing this in a fresh figure.

Fig. 8 represents on a larger scale the parallelogram of the bridge *a b c d*, and the first arch, with all the lines erased that were used for drawing it; the points 1, 2, 3, 4, 5, only being left, as they are required for what follows; first from *a* and *b* draw lines to the vanishing point P, and mark the width of the bridge in perspective;* from the point *g* draw a line to the vanishing point P, cutting *i h* at *k*; then from the points *k h* draw lines to the vanishing point ⊙†. From each of the points 1, 2, 3, 4, 5, draw a line to the vanishing point P, intersecting the line *k* ⊙ at the points 6, 7, 8, 9, 10, from each of which points draw a perpendicular line to the line *h* ⊙; join 12, 6, and 12, 10, and you will have a rectilinear figure for drawing the inner arch corresponding in all its intersecting points with that from which the outer arch was drawn; draw the curve through the points of intersection, and from the point *l* a line to the vanishing point P, cutting the perpendicular line from 10 at 11. Proceed with the second arch in the same manner, and the representation will be completed.

It is necessary to shew the whole of every process by which a drawing is to be put in perspective, as from being acquainted with different ways of producing the same result, one may be serviceable for one purpose, another for some other; so various are the ways of arriving at the same end, that it is not uncommon to see two draughtsmen, working at the same subject, producing fac-simile drawings, and yet finding almost all the points by different processes. That which is accomplished by the fewest possible lines, is always best.

A very simple mode of drawing a series of arches is shewn in figs. 9 and 10. Fig. 9 is part of the elevation of an archway (all that is essential for our purpose). The student will here observe that not a line is thrown away; a quadrant of a circle only is enclosed in a square, with only one diagonal drawn to get the point of intersection for the curve, and this is carried horizontally to the line *a b* at *c* the height of the piers, from where the arches spring, is also carried horizontally to the line *a b* at *d*;

* This is taken here at will, and chosen of a trifling width, the better to understand the problem.

† This vanishing point, from want of space, is out of the picture; nevertheless the student will understand that all lines said to be drawn to it would meet in the same point if continued.

carry these points *c d* to the line *a b*, fig. 10. Upon the line *b e* mark the geometrical width of the piers and arches, with the centre of each arch as at 1, 2, 3; 1, 2, 3, &c.: and carry all these points as before directed to the line *b* ⊙ at 4, 5, 6; 4, 5, 6, &c.: from all the points 4 and 6 draw perpendiculars between the lines *a* ⊙ and *b* ⊙; draw the lines *d* ⊙ and *c* ⊙; draw a perpendicular line from each of the points 5 to the line *d* ⊙ at 7, 7, &c.; join all the points 4, 7, and 6, 7, through which lines the intersections of the line *d* ○ will give points for drawing the curves for fifty arches if required.

Fig. 11, A, represents the common method of drawing a simple pointed arch geometrically, by the intersection of two semicircles; fig. 11, B, represents the same in perspective. This however would be but a clumsy mode of proceeding. Fig. 12, A, is a pointed arch drawn similar to fig. 11, A, enclosed in a rectangular figure, with points of intersection taken as in the semicircular figures, figs. 7 and 9. Fig. 12, B, is the same figure represented in perspective.

Where arches are represented on a large scale, it is necessary to find more points of intersection for drawing the curves. Fig. 13, A, is the geometrical figure of a pointed arch, having three points of intersection, through which to draw the curve; fig. 13, B, is the perspective representation of this figure. Any additional number of intersecting points the draughtsman may require to enable him to describe the curve, may be made in the geometrical drawing.

The student will easily comprehend, from the foregoing examples, that any curve may be put in perspective by enclosing it in a rectilinear figure, getting points of intersection in certain parts of the curve, and then finding their perspective positions. To exercise himself in drawing curvilinear figures in perspective, let him refer to the plate on Conic Sections (Plate VII., Elementary, A, Part IV.) Let him first take the figure of the ellipse; draw the parallelogram in perspective; then the transverse and conjugate axes; divide the transverse axis into 10 perspective divisions, and each of the sides of the parallelogram parallel to the conjugate axis, also into 10 perspective divisions; then draw the lines similar to those in the geometrical figure, and they will give points of intersection through which a curve drawn will represent the ellipse in perspective. So with the figures of the parabola and hyperbola; find the perspective positions of all the points on the geometrical rectangular figures, then draw lines from the respective points to get the perspective positions of the intersections, through which points a curve drawn will represent the figure in perspective. By the foregoing directions the student should be able to draw in perspective the whole of the figures of mouldings given in Plate II. on Drawing.

In a similar manner to that used for drawing the regular figures represented

in Plate XII., may be drawn in perspective the representation of ornaments. To find all the points of intersection for the curve lines in such figures as those of figs. 4, 5, 6, Plate VII., would be an endless labour; but leading points must be found, so as to regulate the height and width of the principal features, at certain distances, and the intermediate parts drawn by the eye. This requires practice; but the student will find, by diligence, that his eye will gradually become accustomed to perspective form and proportion, and in his progress he will discover that much fewer points are required to execute a perspective drawing, than he may be led to imagine at the commencement. To make the rules intelligible, we are compelled at the commencement to go through the whole process, secundum artem; but as we proceed, all extraneous matter is left out; witness the simplicity with which a long series of arches may be drawn by the rules in the example given, figs. 9 and 10, Plate XIII.

The rules and examples given in the preceding pages are sufficient to enable an attentive student to put in perspective the whole of a building; still the complication of parts may render such an attempt a little puzzling; the Author may probably in a Supplementary Part recur to this subject, and from the foregoing matter, (referring to the different problems as he proceeds in the several parts,) from a regular plan, and front and side elevations of some familiar structure, shew how to put the whole in perspective.

CHAPTER X.

ON LIGHT AND SHADE.

It is almost superfluous to attempt an explanation of what is meant by light and shade. Every one must be aware that when the sun shines on any object, it is said to be in light; that if this object is interposed between the sun and another object it casts upon it what is termed a shadow; that those parts of an object that do not face the sun are said to be in shade. Painters make use of the terms light, shade, and middle tint, to express the different gradations; middle

tint, however, may be either light or shadow. An object may be in light, yet that light so subdued as to be quite as dark as some of the parts in shade. This materially depends on the direct or oblique manner in which the sun's rays are received on the object, as also on the local quality of the object to be represented. It may readily be conceived that a newly white-washed building receiving the direct rays of the sun, must appear infinitely brighter than a dusky brick or dark-painted building. If any object stand at an angle with an object in bright light it becomes partially lighted by it; this is called reflected light.* It is usual to represent those shadows cast by one object on another, darker than the object casting the shadow; and in ordinary drawing it is best to follow this rule, though it may not always be correct, for an object of a dark material, casting its shadow on any very light surface, may appear darker than the shadow it casts; the shadow of a dingy brick chimney thrown on a white plaster building would be lighter than the chimney casting the shade. Rules have been given, attempting to regulate the quantities of light and shade in a picture. It has been said that a good picture should consist of one portion of positive dark, one of positive light, and six of middle tint; and numerous examples have been brought forward to prove that some of the finest productions of art derive their excellence from such a distribution; but it is impossible to lay down any fixed rules for the quantities of light and shade; a judicious arrangement of light and shadow constitutes one of the great excellencies of painting; but it is impossible to make a picture from a recipe. Middle tint is most essential to the good effect of a picture, and should occupy the principal portion of the subject; it gives value to the light and to the darker shades; but the quantity must depend on the nature of the subject, the hour of the day intended to be represented, and above all, on the judgment and feeling of the artist. Mr. West, the president of the Royal Academy, in speaking on this subject some half century back, said that the principles of light and shadow might be exemplified by a bunch of grapes. Whether or no the idea originated with this venerable painter is of little importance; the choice of subject for illustrating in a simple manner the beauty of light and shade is most happy; the endless variety of shades cast by the irregular form and disposition of the grapes—the little points of dark in the angular depths between the grapes

* If any one place an object in the sun against a dark curtain, a bust for instance, he will perceive that side of the object on which the sun shines to be in bright light, and the side next the curtain in deep shade; if a sheet of white paper be placed between the object and the curtain, the side in shade becomes instantly lighted up by the rays reflected from the white paper, so as to shew every part distinctly.

—shew admirably how, by a judicious arrangement of light and shade, reflected light and cast shadows, a representation of the most simple object may be made agreeable to the eye.

In landscape painting, the morning and evening are almost always chosen for studying effects for pictures; a finer effect of light and shade being produced from the inclination of the sun's rays at these times; in subjects of buildings the light and shade is better when the sun is higher, as the full advantage of the depth of the shadows is produced by the various projections.

Light and shade is a most valuable adjunct to elevation drawing; it enables the draughtsman to define what is uncertain in mere outline, and to shew the projections of the various parts without the necessity of a section; for instance, fig. 1, Plate XIV., is a representation of a double cross, similar to figs. 3 and 4, Plate XI.; but from this simple outline it is impossible to say whether it is intended to represent an elevation or a plan. Fig. 2 is the same figure, but shaded; here we see at once that it is a solid figure, with the centre square projecting from the other parts, by the shadows thrown under and at the side of it; also that it is a standing figure, from the shadow from its base. The common mode of shading mechanical drawings is to make the width of the shadow equal to the extent of the projection; drawing the shadows at an angle of 45°; thus by measuring the depth of the shadow below the centre square, it will be found that as it is exactly equal to the width of the square, the projecting figure that casts the shadow is a cube. Fig. 3 is the simple outline of a parallelogram, but without the aid of the shadows it is not possible to know precisely what it is intended to represent; but the same figure, with a line of shade under the top line and on one of its sides within the figure, shews at once that it represents a recess, as fig. 4; and again, a similar figure, with a line of shade below the bottom line and on one of the sides without the figure, clearly shews that it represents a projection. Supposing the height of the figure to represent six feet, if the width of the shadow is made one-twelfth the height of the figure it will shew that the projection is six inches. Fig. 6, a rectangular figure with a semicircular top, might be supposed to represent various things, but the slightest indication of shadow, as in figs. 7 and 8, shews immediately the positive figure intended to be represented. The following six figures shew how much is to be conveyed by light and shade. Each of the figs. 9 to 14 in outline is the mere form of a circle; the different manner of shading them shews each to be a different figure; fig. 10 representing a sphere; fig. 11 a cylindrical recess; fig. 12 a cylindrical projection; fig. 13

represents a circular recess forming a portion of a hollow sphere; and fig. 14 a circular projection, forming part of a sphere. Light and shade gives to the same outline a distinct difference of figure, and hence becomes a most valuable assistant to elevation drawing; as we have shewn that by outline and light and shade all the proportions of height, width, and projection of the various parts of an object may be defined.

CHAPTER XI.

But few directions are necessary for the mere purpose of enabling the student to wash in the forms of his shadows; he must be provided with a hair pencil, and a cake of color—either Indian ink, Sepia, or Cologne earth, will answer the purpose. Flatness and equality of strength are most essential; a quantity of the color should be rubbed in a saucer, and diluted to the required strength, which will insure uniformity of tone; the pencil should be kept as full of color as possible, and where it is requisite, as is constantly the case, to leave one part whilst washing the color round the outline of another, the edge of the part left should be quite floating; this will admit of returning to the part before the edges are dry, and obviate any appearance of joining the washes. Great care must be taken to work the shadows clean up to the outline, touching the lines, but not going beyond them; any deviation from this produces a most unpleasing effect. The full depth of the shadows should not be laid on at once, but produced by repeated washes, and the student, in his earliest attempts, will find it of advantage to wash in the first tint very faint; by so doing he will find the color flow more freely, and any trifling error may be more easily remedied. If a dark and light shadow touch one another, fill in both in the first tints, with the same wash, and darken the deepest shade afterwards; this obviates any hard lines which would arise were the shades washed in separately.

Let us go back to our first lesson in elevation drawing, fig. 6, Pl. I., and see how we are to proceed to put in the light and shade. In describing the drawing of this figure, it was stated that the roof projected in front of the cottage one foot; we must therefore draw a faint horizontal line, at the distance of one foot of the

scale, below the lowest line of the roof, and carefully wash in the shadow between the two lines. Suppose the recesses of the windows to be six inches, a faint line must be drawn six inches of the scale below the upper line of each window, and as the shadows fall from left to right (the usual mode of representing them in elevation drawings) a faint line must be drawn six inches from the left side of each window, and the spaces filled in with color. Suppose the recess of the door to be nine inches, a line must be drawn in like manner nine inches below the upper line, and on the left side of the door, and the space filled in with color; this is shewn in fig. 15, Plate XIV. In the side elevation, fig. 7, Plate I., the sloping sides of the roof project one foot beyond the wall, as shewn at 22, 23, fig. 6, Plate I., a faint line must therefore be drawn one foot from the sloping side on the left, and the space filled in with color as shewn in fig. 16, Plate XIV. Thus the two figures 15 and 16 shew by outline the height and width of the several parts, and by the shadows the extent of the recesses and projections, from which a perspective drawing may be made without further directions. In shading elevations, as cast shadows only are represented, they may be made of one uniform tint; but in perspective drawings, when the thicknesses of the parts are represented, the cast shadows should be darker than the side in shade.

In shading perspective drawings, it must be observed that the shadows thrown from the projecting parts follow the same rules as the parts themselves, as shewn in fig. 17, the perspective representation of figs. 15 and 16; the depth of the line of the shadow from the roof must be measured on the line of projection, and a line ruled from it to the vanishing point, which will give the gradual diminution of the width of the shadow as it recedes from the spectator. To find the shadows in the recesses of the windows and the door, those thrown downwards must be measured on the line of projection for finding the perspective heights, and ruled to the vanishing point; those thrown sideways must be measured on the line of projection for finding the width of the parts, and their perspective width found by means of the point of distance (figs. 3, 4, Plate VIII.) That portion of the perspective drawing representing the elevation, fig. 16, would be entirely in shade, but the projecting roof would receive the shadow of the side of the house, and is consequently represented darker than the side of the building that casts the shadow.

To enter into the rules necessary for thoroughly comprehending the projection of shadows, would be overstepping what was proposed in this work; we

must therefore be content with making the shadows equal in width with the extent of the projection; but as the forms of the shadows are not the same as the objects that cast them, we will point out the mode by which the forms are to be ascertained. Let A, fig. 18, be the position of a rod projecting at right angles from a wall; B C the plan of the rod, shewing its length; B D the ground line. From the point A, at an angle of 45°, draw downwards the line A *a*, and from the point C at an angle of 45° draw upwards the line C *c*. The line A *a* shews the direction the shadow of the rod would take on the wall; the line C *c*, where it cuts the line B D at E, shews at what distance the shadow of the rod should terminate. Draw a perpendicular line from E, cutting the line A *a* at F, then A F would be the shadow of a rod projecting at right angles from the point A of the length B C. Let A *b* represent the height of a plane projecting at right angles from the wall of which B C is the length of the projection; from the point *b* draw a line at an angle of 45° to meet the perpendicular E F, then the figure A F *d b* would represent the form of the shadow thrown from such a projecting plane. Such would be the shadow of a shutter opened at right angles. It must then be evident that to get the correct form of the shadows we must have a plan of the projections. Let fig. 19 represent part of the elevation of an entablature, with the plan of the projection of its parts; B represents the extreme projection of the upper part, C the position of the plane on which the shadow is thrown. From the point A draw a line downwards at an angle of 45°, as A *a;* from the point B draw a line upwards at an angle of 45°, till it meets the line C at *b;* from *b* draw a perpendicular line to meet the line A *a*, this will give the depth of the shadow on the plane over the dentils. This plane projects beyond the dentils the distance from C to E. From each of the points D and *c* draw lines at an angle of 45° towards each other, and from the point of intersection of the line drawn from *c* with the line E raise a perpendicular; where this intersects the line from D it gives the depth of the shadows on the dentils. Continue the lines from D and *c*. Where the line from *c* meets the line F draw a perpendicular to meet the line drawn from D; this gives the depth of the shadow thrown by the projection from C to F. From each of the points G and H draw lines downwards at an angle of 45°, and from each of the points J and K draw lines upwards at the same angle; from the points where the lines drawn from J and K intersect the line F draw up perpendicular lines to meet those drawn from G and H, which will give the form of the shadow of the dentil; others can be drawn in the same manner or by measurement. To avoid confusion we will give the depth of the shadow of the

entablature, and the form of the shadow of the capital in a separate figure. Fig. 20 is a similar figure to the last with the addition of the pilaster and capital, both in the elevation and plan. From the points A and 1 draw down the lines A *a** and 1, 2; from the point B draw up the line B *b;* raise a perpendicular from the point *b* cutting A *a* at *a*, from which draw a horizontal line cutting 1, 2, at 2, then the figure A 1, 2, *a* would be the form of the shadow of the entablature without the mouldings. From the points C, D, E, F, draw the lines C *c*, D *d*, E *e*, and F *f*. From the points G and H draw the lines G *g* and H *h;* from the point *g* draw a perpendicular, cutting C *c* and D *d* in the points *c* and *d;* from the point *h* draw a perpendicular cutting the lines E *e* and F *f* in the points *e* and *f*. From the point *c* draw a horizontal line cutting E *e* at 3, and from the point *f* a horizontal line cutting the continued line D *d* at 4, then *c*, 3, *e*, *f*, 4, *d*, is the form of the shadow of the capital of the pilaster. From the points J K draw the lines J *j* and K *k*, and from the points *j* and *k* draw perpendicular lines for the width of the shadow of the pilaster, which will complete the outline of the form of the shadow thrown between the pilasters. The student may here see that the depths of the shadows of the several parts are exactly equal to the projections that cast them, by comparing the shadow with the plan of the projections, 5 6 being equal to 7 10; 5 *e* to 7 11; E *c* to 7 8, &c.

Such are the leading rules for shading mechanical drawings; in working from Nature it is not necessary to be so extremely nice; few artists when so doing project their shadows by rule—they usually wash them in on the spot as they see them, and practice enables them to do so with great accuracy. Much beauty of light and shade is frequently produced by incidental shadows; these we constantly meet with in studying from nature; a passing cloud, trees, buildings, any thing in fact, though not represented in the picture, may cast a shadow, the introduction of which frequently produces a most happy effect; incidental lights are equally advantageous. The most agreeable pictures are those produced by artists who by long assiduity have become so habituated to the rules of perspective, and light and shadow, that when drawing from Nature, they trust to their eye and knowledge without the necessity of having recourse to the ruler and compasses; this, however, can only be the result of long and patient study. "How much liberty may be taken to break through rules, and as the Poet ex-

* It is unnecessary to repeat every time "at angle of 45°," all the inclined lines are to be drawn at this angle, both upwards and downwards.

"presses it, *To snatch a grace beyond the rules of art,* may be a subsequent con-"sideration when the pupils become masters themselves. It is then, when their "genius has received its utmost improvement, that rules may possibly be dis-"pensed with. But let us not destroy the scaffold, until we have raised the "building."*

CHAPTER XII.

ON COLOR.

We have now arrived at a portion of our subject, to lay down rules for which, in the present advanced state of water color painting, is attended with considerable difficulty. In the preceding parts, elevation and perspective drawing both purely mechanical, every line can be accomplished with the ruler and compasses by established rules; so, to a certain extent, is it with light and shade; there are fixed rules for finding the forms of shadows, and a little practice will soon enable the student to wash in his tints with flatness and precision; but color depends principally on feeling, and though much may be done by pointing out the most judicious selection of colors, and those required for mixing the different tints best adapted to the representation of various objects at their respective distances in a picture, still to most persons the aid of a master is very requisite at the commencement.

Water color painting, which is universally made use of for all ordinary purposes, from the rapid improvement it has undergone during the last few years, is almost a new art; half a century back and this art was but little understood; the best works of that period were hardly superior to colored engravings. Drawings of that day were, in fact, made on the same principle as colored prints; the shadows were laid in with grey, and the local color of the various parts washed over light and shadow together; the shading certainly was varied, a bluish grey being used for the distant parts, warm grey for the foreground, and a blending of

* Sir Joshua Reynolds' Discourses on Painting at the Royal Academy.

the two for the middle distance. This style of drawing could be most happily imitated by aquatint engraving, printed in two colors, and the impressions tinted from the original drawings. At the period of which we are speaking, the painters in water colors did not aim at much power, and the proper term applied to their works was tinted drawings; the term paintings, which is applied to the works of art now produced by this material, is far more correct than that of drawings, for they are most unquestionably paintings, and of a high quality, rivalling in many respects the finest works in oil.

It is to be lamented that the artists employed by architects, to execute drawings from their designs, for the most part, have not kept pace with the improvement displayed in other branches of water color painting. It is an ordinary occurrence for an artist to receive from an architect's office, a drawing of some building, to which he has to add the sky and landscape, and too frequently the difficulty is not confined to his having so to arrange his part as to distract the eye from the formality of the design, but the building with which he is forbidden to interfere, is so monotonous and so meagre in colour, that he is fettered in his endeavours to produce an agreeable picture, by being compelled to make his landscape fitting with the building; in artistical language, to have the whole picture in keeping; were the artist to work the landscape to his own feeling, the architectural part would appear like a phantom. The formality of architectural subjects is assigned as a reason for the want of interest often to be observed in their representation. It would be idle to pretend that a drawing of an entirely new building, is capable of producing so pleasing an effect as one representing an ancient edifice; the crumbling quality of old material whatever it may be, the discoloration produced by time, and the diversity of line arising from dilapidation, forming together what is called the picturesque, afford a wider scope for the exercise of the artist's powers; still the representation of a good design, though new, with a judicious foreground and background, and what is most essential in architectural subjects, a well arranged sky, both as to form and color, may be made to produce a most agreeable whole; witness the works of Mackenzie, Nash, &c., &c. There are many, arguing from the works of artists who unmercifully sacrifice accuracy of drawing and truth of light and shadow for what they term breadth of effect, contend that correctness in these matters is a secondary consideration; such however is a gross error, for inaccuracy of drawing is as offensive to a correct eye, as a false note in music is painful to a correct ear. Among the early works of the great Turner, who stands pre-eminent

as a painter in water colours, are to be found many drawings of architectural subjects; these though treated with the greatest simplicity, from the refinement of his taste even at this early period of his career, have never been surpassed; he then attempted to represent nature under her simple effects, but since, he has produced the most marvellous works of art, and it is not affirming too much to say, that those of his latter productions, even with the most extravagant effects, are still faithful representations of the extraordinary appearances in which nature sometimes displays herself. It ought not to be matter for surprise that such works are not generally admired, for they are not generally understood; it requires a refined judgment to fully appreciate such works as, emanating from the most highly cultivated intellect, are addressed to the mind. The great point to keep in view, in making a picture, is to draw the line between a too great subservience to rule, and being led away too far from it, by following the steps of those who produce those catching effects, fascinating at the first view, at the expense of truth.

CHAPTER XIII.

The student, supposing him to have acquired a tolerable freedom in the use of the pencil by working his drawings in one color—that is, that he has acquired a facility in drawing outlines, and putting in the light and shadow, from drawings, prints, and from nature, which it has been our aim to assist him in effecting—may proceed with color. The first necessary preliminary is to provide himself with the requisite materials, and to do this, without the assistance of some person conversant with them, he would find himself a little puzzled. Every Artists'-colorman has a collection of from fifty to sixty colors; many of these, for general purposes, are worse than useless; some are expressly for flower-painting, others for miniatures, &c.; a collection of twelve colours is ample for all the ordinary parts of an architectural or landscape drawing. Artists differ a little in the choice of colors, but the following list embraces sufficient for all

general purposes :—1. Indigo; 2. French Blue ;* 3. Gamboge; 4. Yellow Ochre; 5. Roman Ochre; 6. Raw Sienna; 7. Burnt Sienna; 8. Venetian Red; 9. Crimson Lake; 10. Cologne Earth; 11. Vandyke Brown; 12. Lamp Black. Sometimes the introduction of an extra bright bit of color on a figure, piece of drapery, or some local object, gives great zest to a drawing; for this purpose, colors brighter than any in the foregoing list are required: as vermilion for an extra bright red; Naples yellow, or chrome, for an extra bright yellow, &c.; but these colors should not be used for putting in the general effect. In addition to the colors, the student must provide himself with three or four hair pencils and a large flat brush; skies and large masses are always best washed in with a large pencil, it enables the artist to work with more freedom; the under-touches of small parts, such as the deepest shades in ornamental work, require a fine-pointed pencil. The improvement in the manufacture of the materials used in water-color painting, has kept pace with the improvement in their use, and the student, before he commences, should be careful in his choice. There are numerous advertisers of cheap water-colors, but as the best quality is not very expensive, it is advisable to go at once to a respectable dealer† and procure the requisite articles. A good deal depends on the choice of paper, but of this article there is so much variety, both in size and quality, that it is difficult to specify any particular sort; stout paper (not cardboard) is preferable to thin paper, and it should not be over smooth; imperial drawing paper (not hotpressed) answers well for ordinary drawings. Let us then suppose the student to have completed his outline, and ready to commence coloring. In drawing architectural outlines, the hands, the rulers, and the Indian rubber are so constantly passing over the paper, that it becomes frequently both greasy and dirty; the whole surface of the paper therefore should be washed with water by means of a flat brush or a sponge; the latter is best if it can be used with sufficient delicacy, so as to avoid obliterating the outline; should the paper be very greasy, a little gall added to the water will be found of advantage. Before the paper becomes thoroughly dry from this ablution, the first large masses of color should be washed on; the colour runs more

* This is a color prepared to imitate an expensive one called ultramarine, and is superior to it in respect of its working with more freedom.

† During the last few years, the increase of manufacturers and dealers in all things appertaining to this art has been immense, and there are doubtless many highly respectable houses besides the undermentioned; from any of these, however, the quality of the goods may be relied on :—Newman, Soho Square; Ackerman, Strand and Regent Street; Rowney, and Windsor and Newton, Rathbone Place; Roberson, Long Acre; and Smith, Tichborne Street.

freely, and it enables theartist to take his pencil from one part to another, without the edges of the part left getting dry before he can return to it.

It is usual to commence by laying the color for the sky. For architectural subjects, grey skies have generally the best effect; the building forming the principal feature, should be thrown out as much as possible by the secondary parts, and buildings being generally represented of a warmish yellow, approaching to orange, are best relieved by grey. Architectural subjects, consisting of a multiplicity of straight lines, should be relieved by a diversity of form in the sky ; and a cloudy sky, the clouds having a rotundity of form, is best suited to this class of subjects; a small quantity of pure blue may be introduced with good effect, but it should be towards the upper part, and made to appear as if seen through openings in the clouds. The student must carefully avoid, in sketching the forms of clouds, following the sloping lines of the architecture, but rather endeavour to bring them in an opposite direction, and, as much as possible, bring the dark clouds against the light side of the building, and relieve the dark side, if admissible, by light ones; the opposition produced by attending judiciously to these remarks, forms in a picture what is termed effect. The forms of the clouds being sketched, a grey, made by a mixture of French blue and Venetian red, with a very small addition of lake, should be washed evenly nearly all over the sky, leaving only the bright lights of the clouds; this tint will form the lightest shade of the clouds, and should be allowed to dry before the next tint is laid on. The several shades of the clouds must then be washed in, one over the other, till the full depth of the darkest cloud is laid in; where the clouds are darkest, a little indigo may be added to the grey above. The tints of the clouds must be varied a little, some cooler and some warmer ;* a little pure French blue may now be laid on to represent patches of the blue sky seen through openings in the clouds.†

In proceeding with the building, the ordinary process is to commence by putting in the shadows; as a general color for these, Venetian red and indigo may be used; if the local color of the building be yellow, a little lake added to

* Blue is a cold color, red and yellow warm ; the tones of color are said to be cool or warm as either of these colors preponderates. Thus a little lake added to a wash of blue in a sky, not sufficient to make it purple, is called a warm blue.

† The student, as he proceeds, will acquire the power, in the first process of laying in the clouds, to vary the tints according to his feeling, making in his first wash one part darker than another, and also changing the tone of color—making one portion a little cooler, another a little warmer ; he will also, by practice, be able to put in a second wash of color before the first dries ; but at the commencement, unless he allow one wash to dry before beginning another, he will be sure to find himself in trouble.

the red and blue will prevent any greenish appearance in the shadow, after the local color is put on. Lamp black and lake form a good mixture for putting in the cast shadows, but care must be taken that the latter color is not too violent. In an attentive observance of nature, it will be seen that few surfaces present one even color; almost every object, on close inspection, has a decided variety in its tones; some a little brighter, some a little more grey. These varieties of tone in nature, may in the representation be a little exaggerated; one simple wash of color over the face of a building has a tame effect, and gives to a drawing the appearance of a colored print. Supposing the edifice to be of stone, the general tone of which is yellowish, inclining to orange, mix several tints in separate saucers:—1. Venetian red and yellow ochre, the red predominating; 2. Yellow ochre pure; 3. The two just mentioned equally mixed; these will give you orange, yellow, and pale orange; 4. The grey made with lamp black and lake, very pale. Fill the pencil with one of the warm tints and commence at the top corner of the building in light, nearest the shaded side, and continue washing over the whole face of the building, changing the tints from time to time from the different saucers, and running one tint into the other; this will produce a pleasing variety of tones; and occasionally leave a sharp thin streak of light to represent the divisions between the stones, taking care that those representing the horizontal divisions follow the perspective directions the lines should take. If the building be of brick, both the light and shade must have more strength of color. For the shadows, Venetian red, indigo, and burnt sienna may be used; occasionally a small portion of lake may be added. For the lights,—1. Venetian red and yellow ochre; 2. Burnt sienna and lake; 3. A mixture of the two; 4. The same grey as the last. These tints should be laid in similar to the four above-named for representing stone, and small spaces left between the color, here and there, to indicate the mortar between the bricks. Roofs of tile may be colored similar to brick, but, being usually of a darker tone, burnt sienna should be used more freely than yellow ochre. Slates may be represented with a mixture of indigo, Venetian red, lake, and a small quantity of yellow ochre. Windows, from their reflecting any objects within their range, may be represented in a variety of ways; sometimes they appear so intensely bright as to dazzle the eye, at times they reflect the deepest blue, at others dark bottle-green; the most usual mode of representing them is by a moderately dark blue grey, with occasional reflections of light; dark reflections in the windows, on the light side of the building and vice versâ, produce the best relief.

Much judgment is required in the arrangement of the landscape, so as to divert the eye from the rigid forms unavoidable in architectural representations. Branches of trees thrown out so as occasionally to project beyond an angle of the building to break a long line, and by a little light and playful foliage take off from the weight of the structure, have great value, but care must be taken, in so doing, that no part is hidden essential to the development of the architect's design. The foreground is where the artist has the best opportunity of exercising his judgment and imagination; he is here unfettered by rules in managing his light and shade, and by various manœuvres he may introduce form and color so as to give considerable effect to the principal subject; the sweep of a road or path, the introduction of circular or oval beds of flowers, shrubs, &c., afford ample opportunity for giving interest and diversity of form; and the introduction of such objects as a garden roller, watering pot, &c. &c., insignificant as they may be looked upon, produce, by a judicious treatment, both a useful and pleasing effect. It is impossible at present to enter into the minutiæ of coloring landscape; the variety of tints in foliage is endless, embracing all the gradations from the fresh green of a spring morning, to the almost red tone of an autumn evening. The color of an object depends entirely on the effect under which it is seen; for the same object seen on a cool grey morning, which may then appear of a cold grey or white, will, under an effect from a setting sun, appear of an intense orange. There are few who do not know that the mixture of blue and yellow produces green; but as there are several blues and many yellows, the variety of greens to be made from them is interminable. Gamboge, indigo, and burnt sienna are the ordinary colors used for producing green; indigo and gamboge produce a fresh green; the more the blue predominates the cooler is the green. Burnt sienna added to the above produces warm green, and the more predominant the sienna the warmer will be the tone. Raw sienna and indigo form a good color for the lights on foliage; Roman ochre* and indigo is useful for dark trees and shrubs, as is yellow ochre and indigo for sober greens; where great depths are required, lamp black and gamboge may be used, and a trifling quantity of burnt sienna will give it warmth. Great care must be taken by the young artist to avoid making his pictures too green; to prevent this, it is best to lay in all the shadows of the foliage with Venetian red and indigo, with a slight addition of lake; in this grey the

* Where force of color is required, Roman ochre may be used as a substitute for yellow ochre, or combined with it.

red must preponderate much more than in that used for the shadows of buildings; as green, which will be washed over it, always neutralises red, so red will always be found to neutralise green. The observation above, cautioning the student against making the color of foliage too generally local, will apply to almost all objects to be delineated. One of the great excellencies in a picture, is the approximation only, in its general tones, to the local color of the real matter; every thing being viewed from some distance, the tones necessarily appear subdued, and partake more or less of grey, and the student will find more difficulty in producing a grey sober picture, than a bright gaudy one. We must now, at all events for a season, take leave of the reader; we have already exceeded the limit allotted to this portion of the work, but trust, in its progress, to be allowed an additional space to introduce on each part of our subject a little supplementary matter with some additional Plates.

Division B.

PRACTICAL.—ON CONSTRUCTIVE ART.

THE GIRARD COLLEGE FOR ORPHANS.

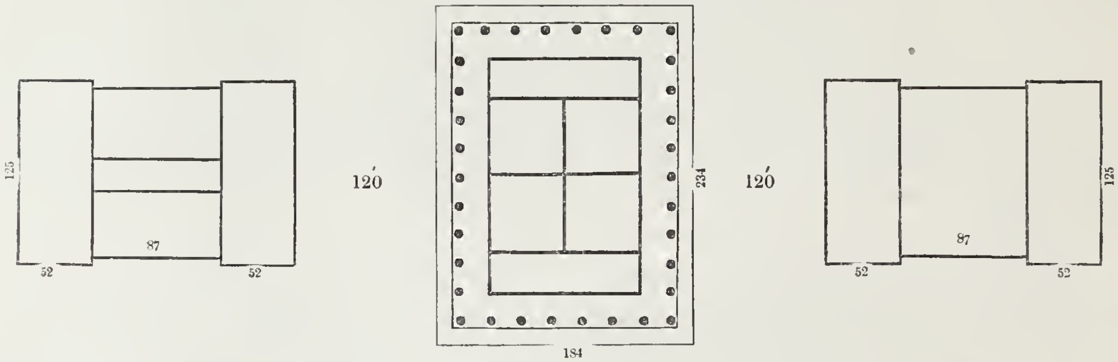
This establishment is situated in the North Western environs of Philadelphia, on a tract of land containing forty-five acres. Its founder, Stephen Girard, was born in Bordeaux, on the 20th of May, 1750; and died in Philadelphia on the 26th of December, 1831. He commenced the world in extreme poverty, from which he emerged with steady progress, until he attained an unrivalled eminence both as a Shipping Merchant and a Banker:—by these pursuits he amassed an immense fortune, nearly the whole of which he bequeathed to benevolent objects.

For the endowment of the College he appropriated *two millions of dollars;* and further provided, that if the interest of what may be left of that sum, after the buildings are constructed and furnished, should prove inadequate to the support and education of all the "poor white male orphans" who may apply for admission; then such further sum shall be taken from the final residuary fund, (consisting of several millions of dollars), as may be necessary to construct as many additional buildings as may be required to accommodate and educate all the additional pupils who apply for admission.

The buildings provided for by the will, as a nucleus to the establishment, are "a permanent College, with suitable out-buildings, sufficiently spacious for the residence and accommodation of at least three hundred scholars, with the requisite teachers and other persons necessary in such an institution."—In reference to the College, Mr. Girard directs that, "it shall be at least one hundred and ten feet front, east and west, and one hundred and sixty feet, north and south;" that "it shall be three stories in height, each story at least fifteen feet high in the clear from the floor to the cornice;" and that "in each

story there shall be four rooms; each room not less than fifty feet square in the clear; the four rooms on each floor to occupy the whole space east and west on such floor or story, and the middle of the building north and south, so that in the north of the building, and in the south thereof, there may remain a space of equal dimensions, for an entry or hall in each for stairs and landings;" "the steps of the stairs to be made of smooth white marble, with plain square edges;" "the outside walls to be faced with slabs or blocks, of marble or granite, at least two feet thick;" and "the floors and landings, as well as the roof, to be covered with marble slabs."

The designs for the establishment were made by Thomas U. Walter, Architect, of Philadelphia, and are now being executed under his directions. The accompanying plates exhibit the details of the plan of the main building with the four out-buildings, and the following diagram shows their relative position.



The centre building covers a space of 184 by 243 feet; it consists of an octostyle, peripteral superstructure composed in the Corinthian order of Grecian Architecture, resting on a base of twelve steps extending around the whole edifice;—a pyramidal appearance is thus given to the substructure, and a means of approach afforded to the porticoes on every side. The dimensions of the stylobate are 159 by 217 feet, and the cell or body of the building measures 111 by 169 feet. The whole height from the ground to the top of the pediment is above 97 feet.

The columns are thirty-four in number; the diameter of the shaft at the top of the base is six feet, and at the bottom of the capital five feet; the height of the capital is eight feet five inches, and its width from the extreme corners of the abacus, nine feet; the whole height of the column, including capital and base, is fifty-five feet.

The entablature is sixteen feet six inches high, and the greatest projection of the cornice from the face of the frieze is four feet nine inches.

The capitals of the columns are proportioned from those of the monument of Lysicrates, at Athens; they are divided in height into four courses; the first embraces the water-leaf, and consists of a single stone of sixteen inches in thickness; the second course is also composed of a single stone, the height of which is two feet ten inches; the annular row of acanthus leaves occupies the whole of this course;—the third division embraces the volutes and cauliculi; this course, which is likewise two feet ten inches in height, is composed of two pieces, having the vertical joint between the cauliculi, on two opposite faces;—the fourth, or upper course, being the abacus, is one foot five inches in height.

The doors of entrance are in the centre of the north and south fronts; they are each sixteen feet wide in the clear by thirty-two feet high; their outside finish consists of *antepagmenta* of two feet seven inches wide, the *supercilium* of which is surmounted with a frieze and cornice;—the cornice is supported by rich consoles of six-and-a-half feet in height, and the cymatium is ornamented with sculptured honeysuckles.

The exterior of the whole structure is composed of fine white marble obtained from quarries in Pennsylvania and Massachusetts. The columns are composed of frustra measuring from three to six feet in height; the bases each consist of a single piece, the diameter of which is upwards of nine feet; the capitals are all wrought on the ground, and present an admirable specimen of architectural carving:—the whole cost of each column, including its capital and base, is *thirteen thousand dollars.*

The vestibules in the first story, and the lobbies in the second and third stories, are all vaulted from marble entablatures supported by *antæ* and columns, the shafts of which are each composed of a single stone.

There are sixteen columns and as many antæ in each story; those in the first story are Ionic from the temple on the river Ilissus, and those in the second and third are modifications of the Corinthian.

The building is three stories in height, measuring twenty-five feet from floor to floor; it contains four rooms on every floor, each of which is fifty feet square in the clear. The first and second stories are vaulted with groin arches, and the third with pendentive domes falling below the plane of the roof, and lighted with skylights of 16 feet in diameter.

The roof is composed of marble slabs of four feet by four feet six inches,

supported on nine inch walls; the joints are covered with saddle tiles, and the slabs are so formed as to render the whole water-tight without the use of cement.

It being altogether of recent date, Anglo-American architecture has, instead of passing *through*, passed *over* that phase of the art which was produced by European "*mediævalism.*" It was but natural, perhaps, that a people compelled to adopt a style ready shaped out for them, should take up that which had been proclaimed by the universal consent of all civilized nations to be the most perfect the world had ever beheld,—the one upon which the art had been *anchored* ever since the so-called Revival of the arts, but which, though professedly imitated, had been only to a certain extent, and had been corrupted in modern times by so many innovations, and by so many elements altogether foreign to its constitution having been mixed up with it, as to have lost its original character. In the idea of adopting and re-establishing Grecian architecture in all its purity, there was a temptation not to be resisted. Admiration for it was secured beforehand by the dazzling halo of its classical fame; added to which it possessed another strong recommendation, namely, its extreme *simplicity*. It required, or seemed to require, nothing more than an acquaintance with the Grecian orders, and fidelity of imitation in copying them; for which last purpose numerous architectural publications supplied the requisite studies and authorities. European artists and archæologists had carefully delineated and explained the remaining monuments of Greece; but, availing themselves of such preliminary labours, the architects of America aimed at nothing less than the exemplifying in their own structures the practical restoration of Grecian architecture and Grecian taste. That style accordingly began to be employed by them indiscriminately for purposes the most opposite—not merely for public edifices of monumental character, but for domestic buildings. Modern country residences were put into the costume of Grecian villas, or rather were made to look at the first glance like Grecian temples, by the mere addition of Greek porticos or colonnades to the house itself; a mistake that has been committed here at home.

It was not perceived that in the fancied simplicity so attained, there was, instead of the *unity* almost indispensable for simplicity, a marked *duality*,—that of two opposite systems, the antique and the modern, not artistically blended together so as to compose a third system out of the elements of the other two, but left to conflict together in harsh contrast, the one by the side of the other. It was not perceived—does not even seem to have been so much as suspected—that the very *simplicity* of Grecian architecture, the quality for which it is so

loudly extolled, admirable as it is in itself, more or less unfits it for actual practice in modern times. Architecture must necessarily comply with the necessities of building, with the circumstances and habits of the age and the people who employ it. To endeavour to accommodate buildings to a style which never contemplated, and therefore never provided for, what is demanded by the present state of civilization, is a most perverse course—one totally opposite to that by which all styles have naturally grown up, and been moulded according to the actual exigencies of their own period. Excellent as it was for Greece itself, Grecian architecture is by far too limited to be at all suitable as a general system at the present day. While it affords nothing but *columniation*, (which in modern buildings, so far from being at all needed, is at the best only embellishment,) it so obstinately rejects all besides, that the more we endeavour to adhere strictly to the imperfect models it holds out to us—imperfect with regard to what we really require—the greater are the incongruities we fall into, and the more evident do we make our misapprehension of the style we profess to admire. The most correct imitation can produce nothing more than the semblance of a Greek temple; and provided the nature of the structure itself be such that its exterior can readily be made to assume such form, the imitation may be perfect. Such is the case with the Madeleine at Paris, and the Walhalla near Regensburg (Ratisbon), in Bavaria; the former of which is externally the model of an octostyle Corinthian, the other of an octostyle Doric temple, it being an avowed imitation, or even a facsimile, of the Athenian Parthenon, with the exception of its sculpture. In those instances—merely exceptional ones—there is no obvious inconsistency; because windows, that is, windows in the walls, could be dispensed with, the interior being lighted entirely from the roof; besides which, the interior is what the exterior bespeaks it to be, namely, a single large room, answering to the *cella* of a temple, and occupying the entire height of the structure from floor to roof. In each case the plan itself, and the constitution of the building, are so exceedingly simple, that there is nothing which directly militates against the model taken for the occasion. Yet those two edifices are, as has already been observed, extreme and exceptional instances, which only serve to prove how altogether unfit is Greek architecture for general purposes,—and Greek temple architecture most of all. When the building is divided within into stories, by floors, and consequently all but the uppermost story must be lighted by windows in the walls, a character totally different from that of the classical temple style must inevitably take

place; wherefore, to adhere strictly to the latter, becomes impossible, and as the attempt must prove abortive, it is one that ought not to be made.

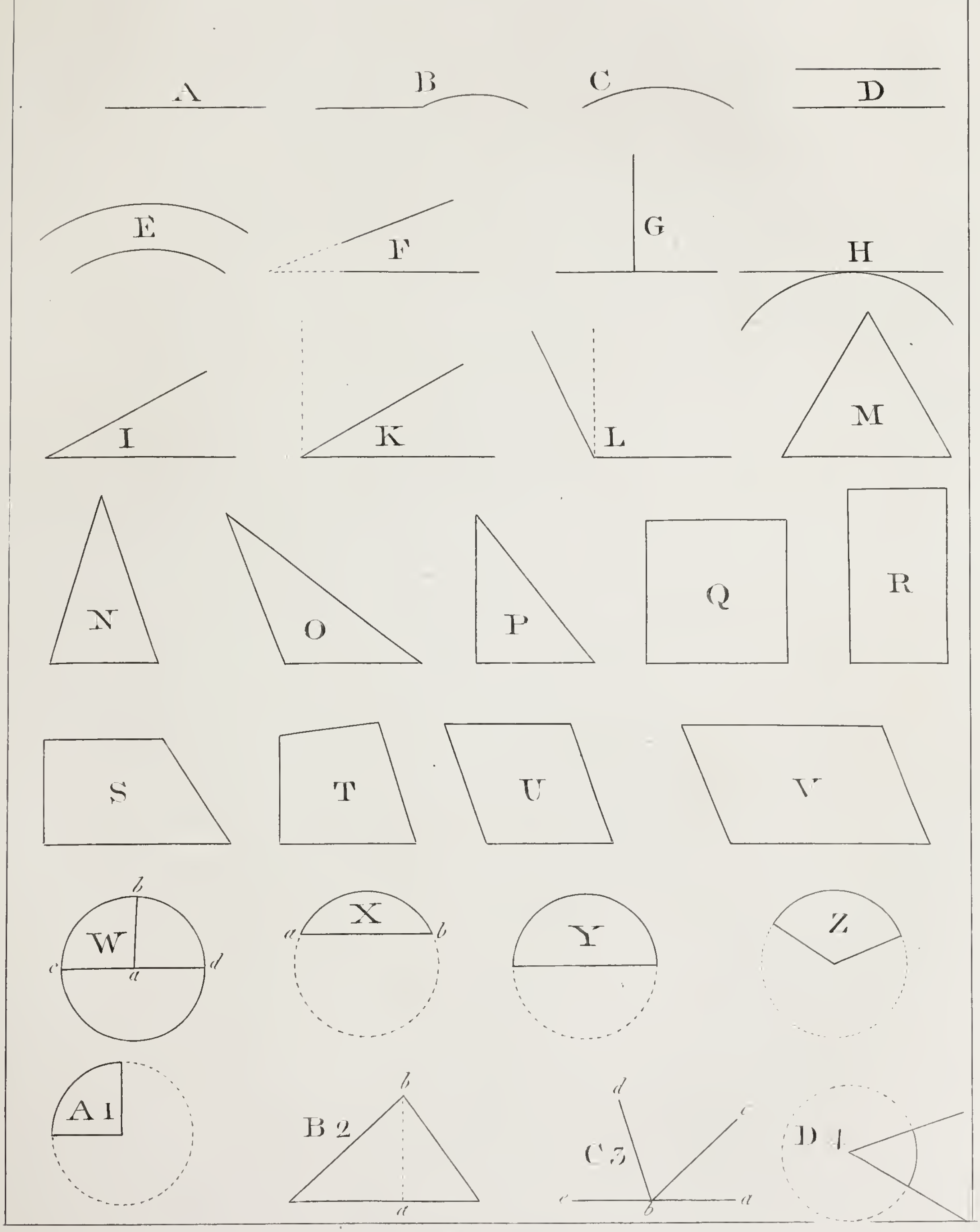
After these remarks, it cannot be supposed that the Girard College is here offered as an example to be followed, but it is one that holds out an instructive lesson, and is one from which much may be gathered. Still it is certainly of interest as a monumental work of modern times, executed in the most costly and durable materials, without regard to expense; and serves to make evident both what can and what cannot be accomplished by strict adherence to Greek authority, as far as such precedent goes. The order itself is upon a scale that may well be termed colossal in comparison with that of the largest Greek temples, and being applied strictly in accordance with the arrangement of a classical peristylar edifice, it affords a magnificent and impressive representation of Grecian architecture. But, though both on that account, and as a monumental fabric constructed of and covered with marble, the main building of the Girard College is entitled to admiration, and may fairly be classed among the most remarkable works of modern times, it is by no means perfectly satisfactory as a production of art. While originality, either of conception or design, is disclaimed for it altogether, the necessity for windows has prevented that consistent imitation of the antique which excuses the want of originality, and renders mere imitation a merit.

As a practical style, Greek architecture has now had a tolerably fair trial, and has, after many experiments, been found so inadequate to modern purposes, even under the most favourable circumstances, that the affectation of it is beginning to be laid aside, and architectural taste has now veered about from ultra-Greek to ultra-Italian on the one hand, and the mediæval styles on the other. The more perfect a style is in relation to the particular purposes it was intended for, and the particular conditions it was expressly adapted to, the less suitable is it for general application, or for buildings that are at all differently constituted from those edifices which are monuments of such style. Unfortunately, while Greek architecture demands columniation, as essential to its characteristic physiognomy, it rejects *fenestration*, as being contrary, or even destructive to, that physiognomy; yet though columns may be applied for the nonce, windows cannot be dispensed with at pleasure. Had the main building of the Girard College been a single spacious and lofty apartment, intended to serve as the College Hall, and accordingly admitted of being lighted from the roof, its temple character could have

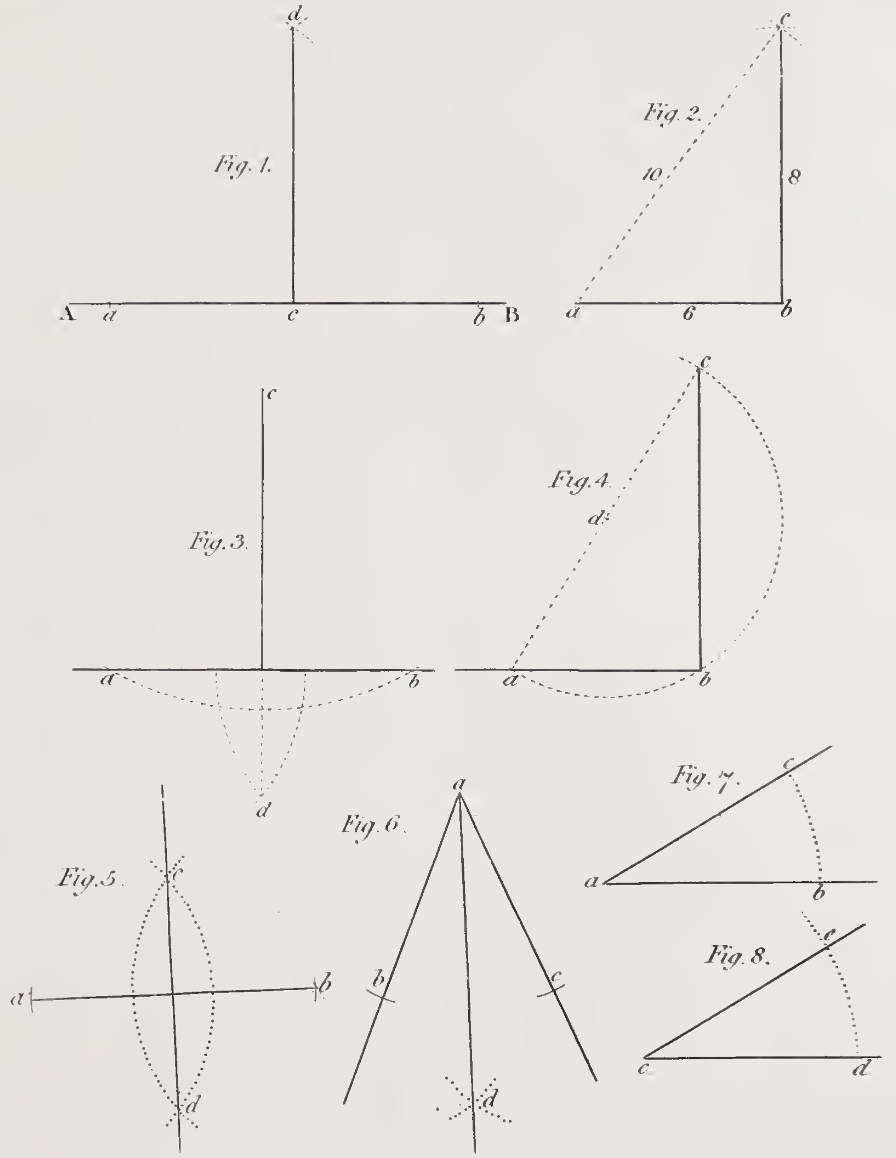
been consistently kept up, and the exterior and interior of the structure would then have corresponded with each other; the former indicating, and the latter being, a single room analogous to the *cella* of an ancient peripteral temple. At present the degree of resemblance obtained by scrupulous regard to Greek precedent, as far as such precedent could be followed, amounts to no more than very imperfect imitation. Now, in art, whereas free imitation is not only excusable but laudable, imperfect imitation, occasioned by the impossibility of adhering to the model which is avowedly intended to be copied, inevitably partakes more or less of mere *mimicry*. As to the American architects, it is no wonder that they should have fallen into a mistake which both the doctrine and the practice of their European brethren in modern times had prepared for them by cherishing error all along. No doubt architecture requires to be governed by immutable principles; but obstinate fixity of forms and stagnation of ideas are not only distinct from, but subversive of, all genuine principles, both of composition and construction. To use an Americanism, Architecture has, in consequence of such unhappy error, been brought to "a complete fix,"—to a dead stand—without any alternative than that of oscillating between former styles, be they Greek, Gothic, or any other. Every step is backwards, without any effort being made to take a single one forward. We are well aware that architecture cannot be made to advance by sudden leaps and jumps; the progress to a style accommodated to our actual social wants and habits, must of necessity be a gradual one, and not only gradual but slow; but unless a beginning be made somewhere —unless the first step be taken—we must for ever remain just where we now are, and be content to be the literal copyists of those who have gone before us. As an art, architecture has, it seems, run its course; it can accomplish nothing more than it already has done;—such is the opinion which is, we do not say openly avowed, but betrayed, by present practice, and by that complaisant criticism which bestows on works of mere reproduction the encomiums that should be reserved for originality—for genuine artistic conception.

THE FIVE ENGRAVINGS.

Plate 1.



John Weale, May 1 1847.



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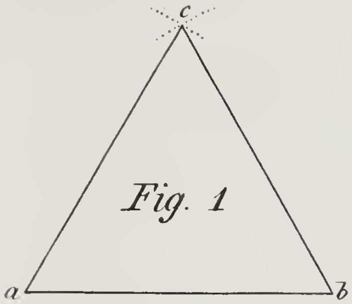
c
Fig. 1
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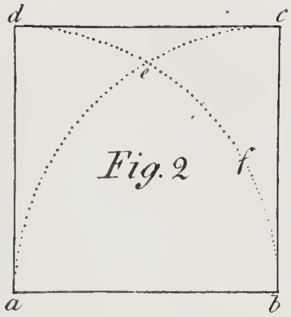
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Fig. 2
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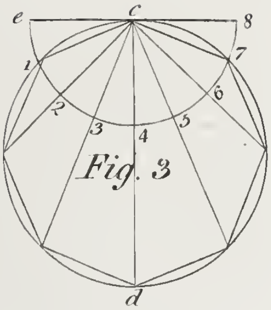
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Fig. 3
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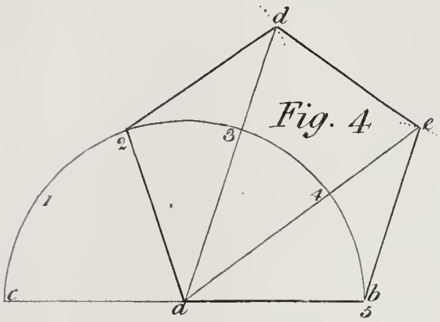
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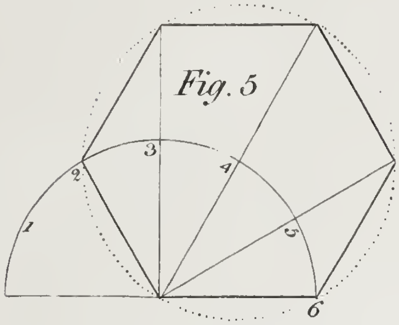
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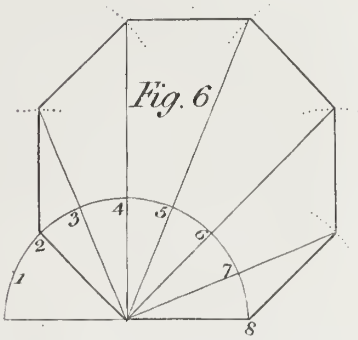
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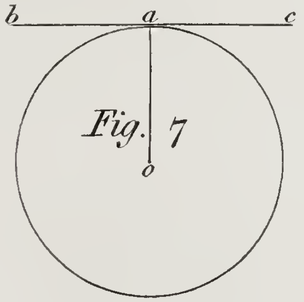
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Fig. 7
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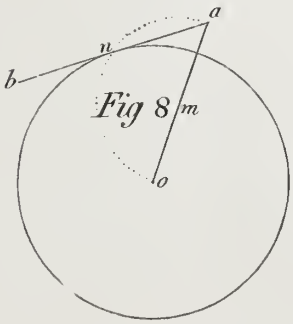
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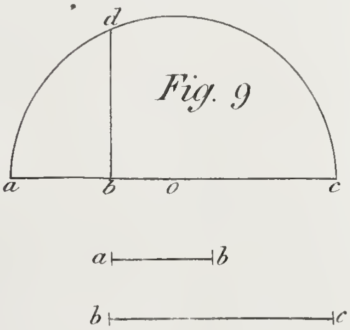
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Fig. 9
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c

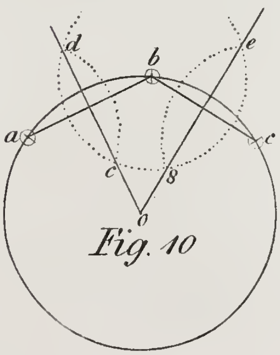
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Fig. 10

Fig. 11

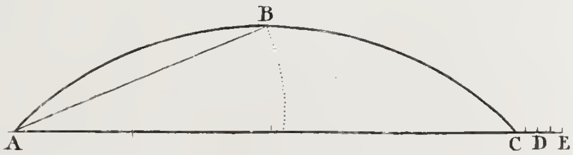
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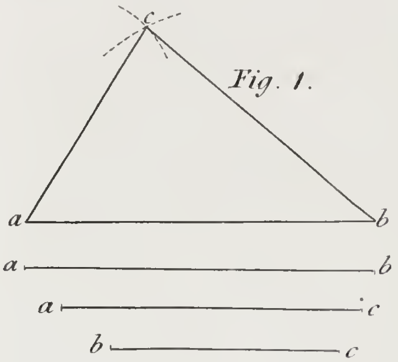
Fig. 1.



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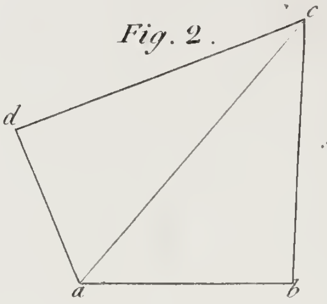

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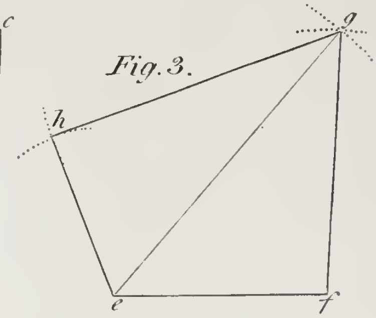

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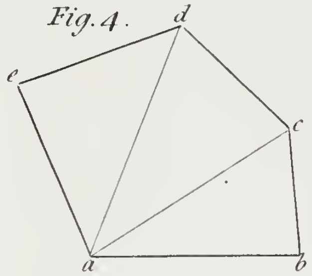

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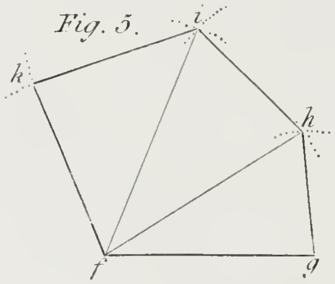

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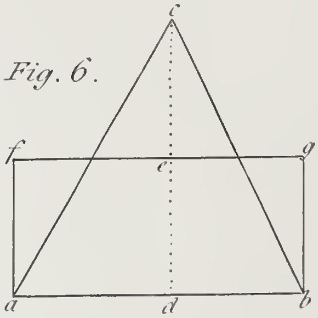

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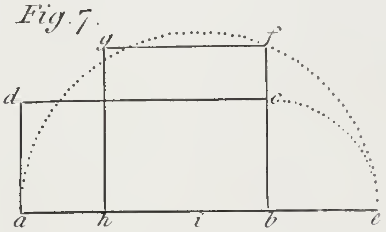

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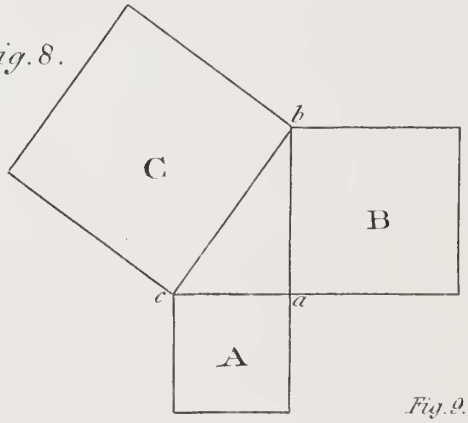

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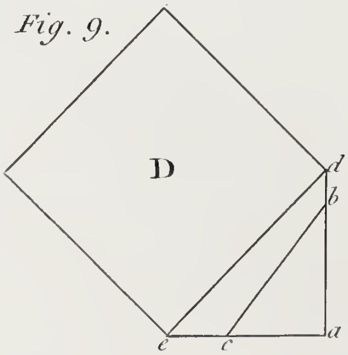
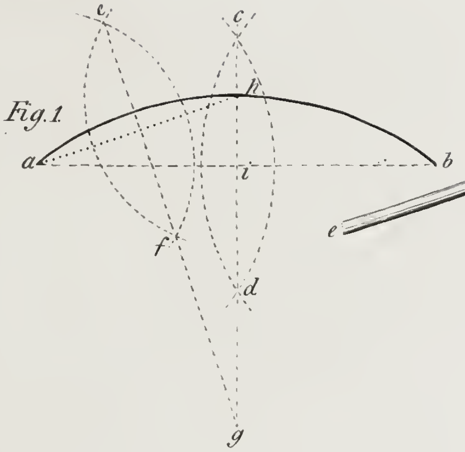


Fig. 9.

Fig. 9.

Fig. 9.

Fig. 1.



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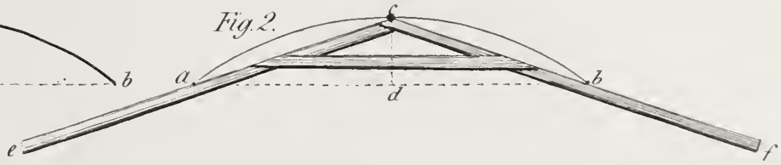

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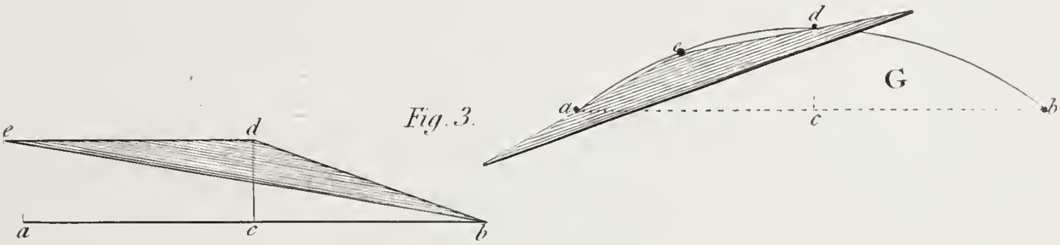

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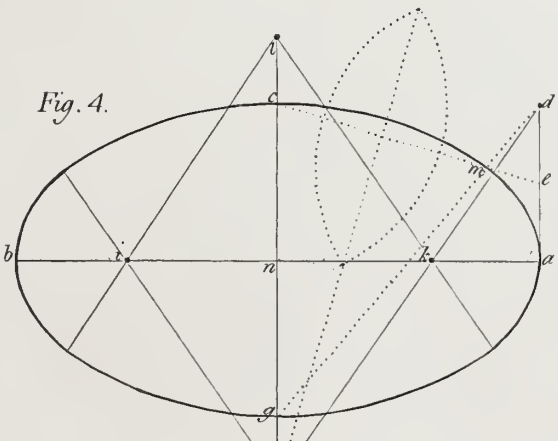

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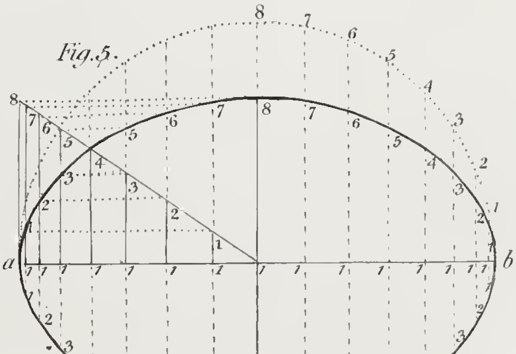

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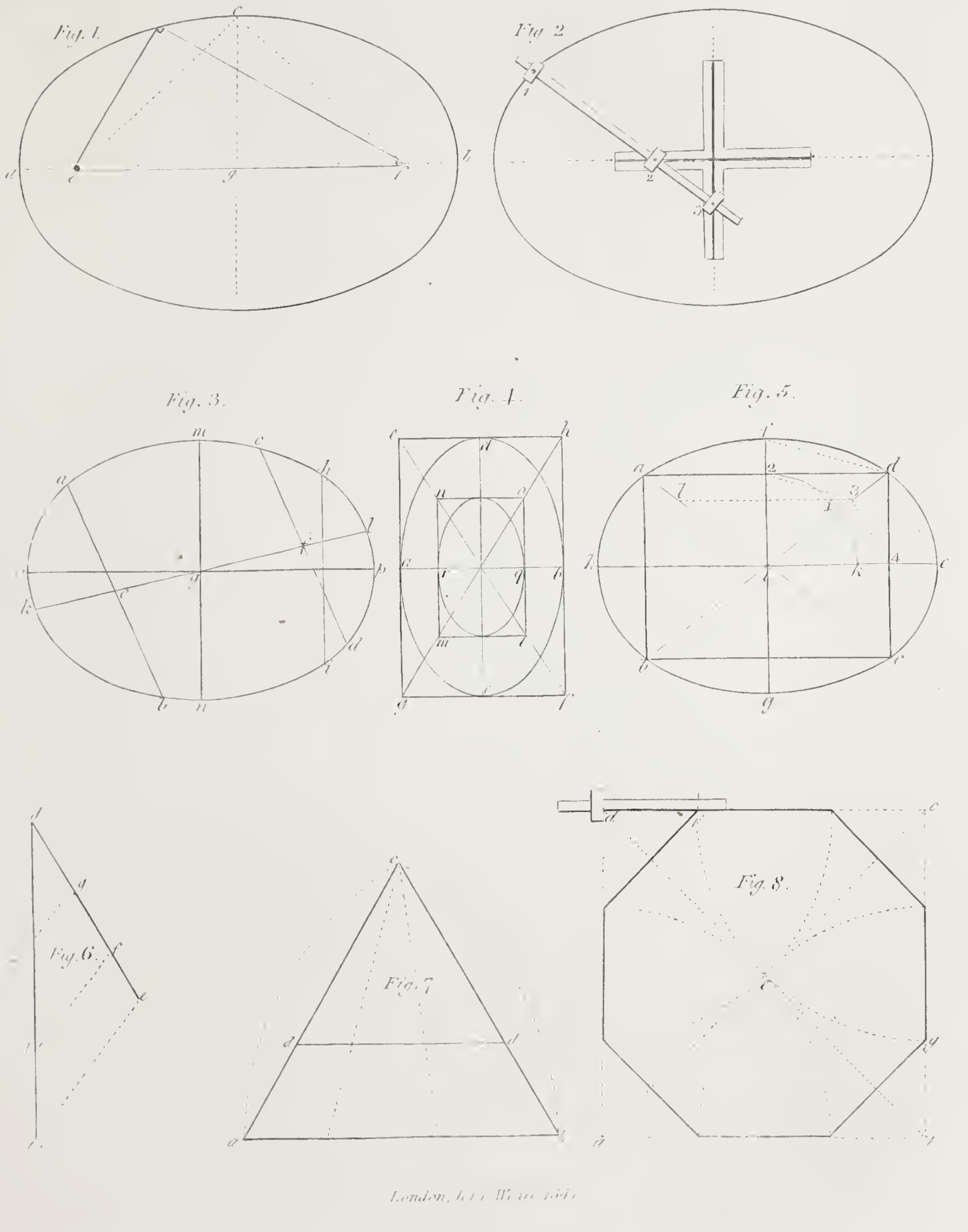
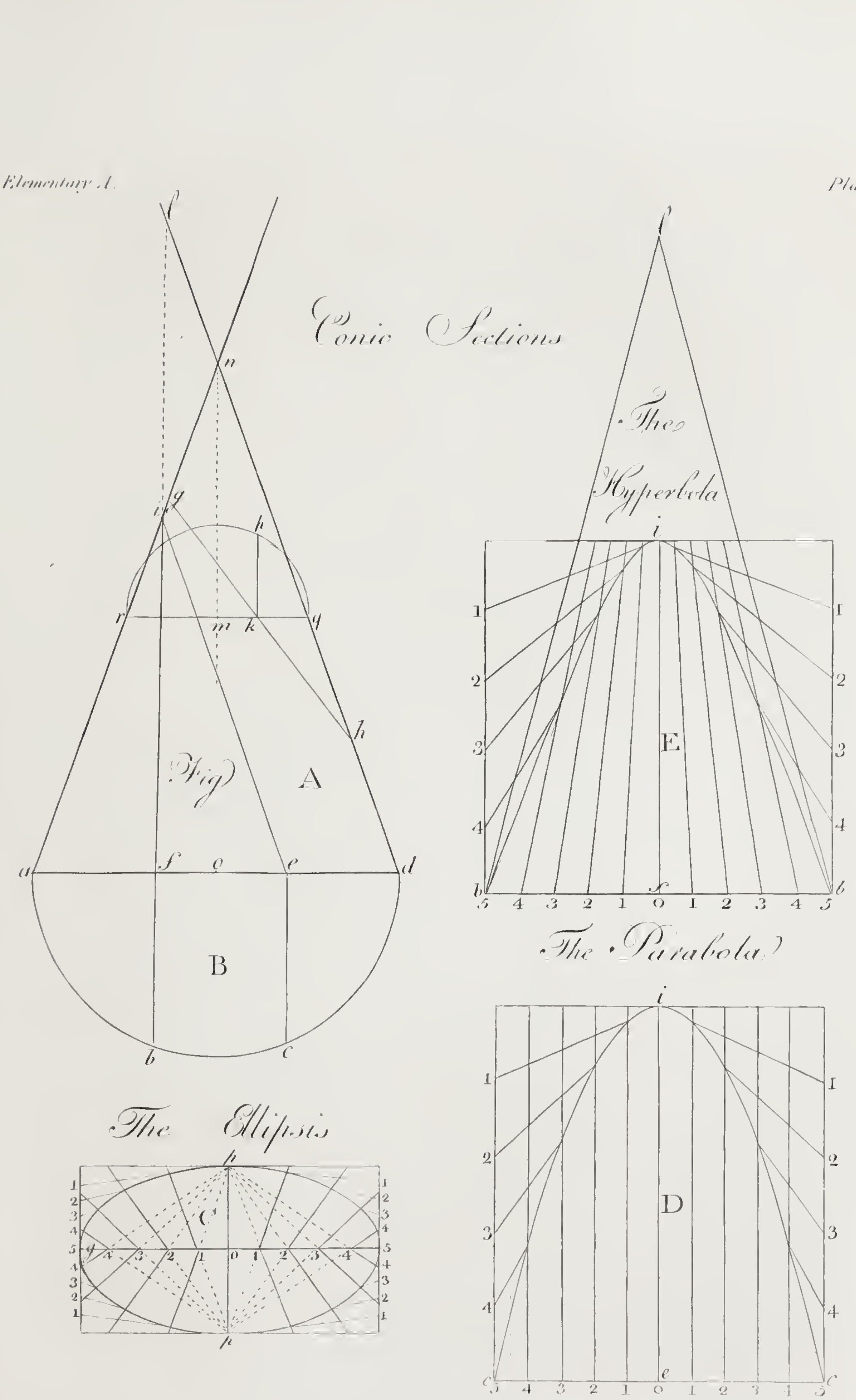


London, [illegible]

Conic Sections



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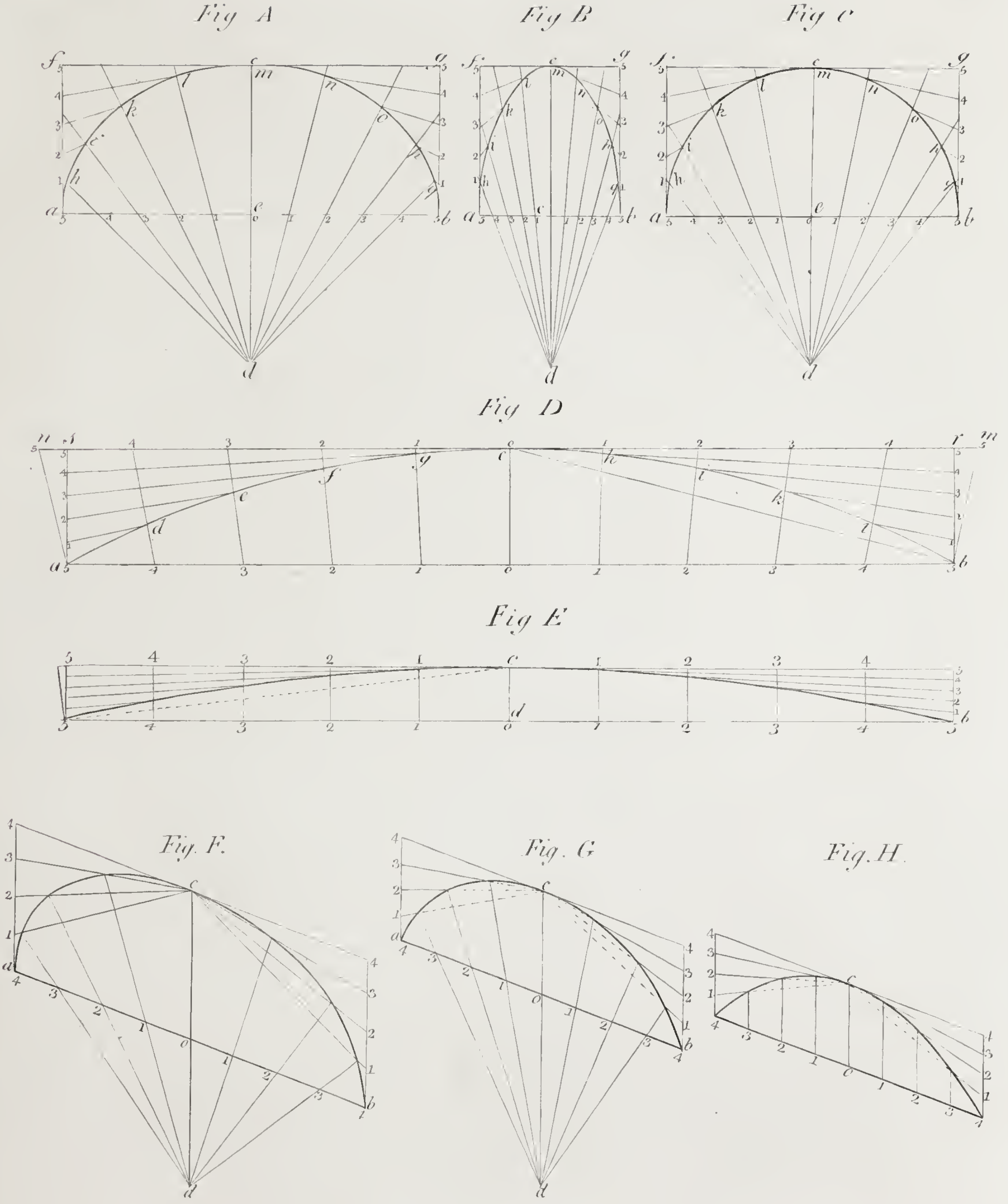

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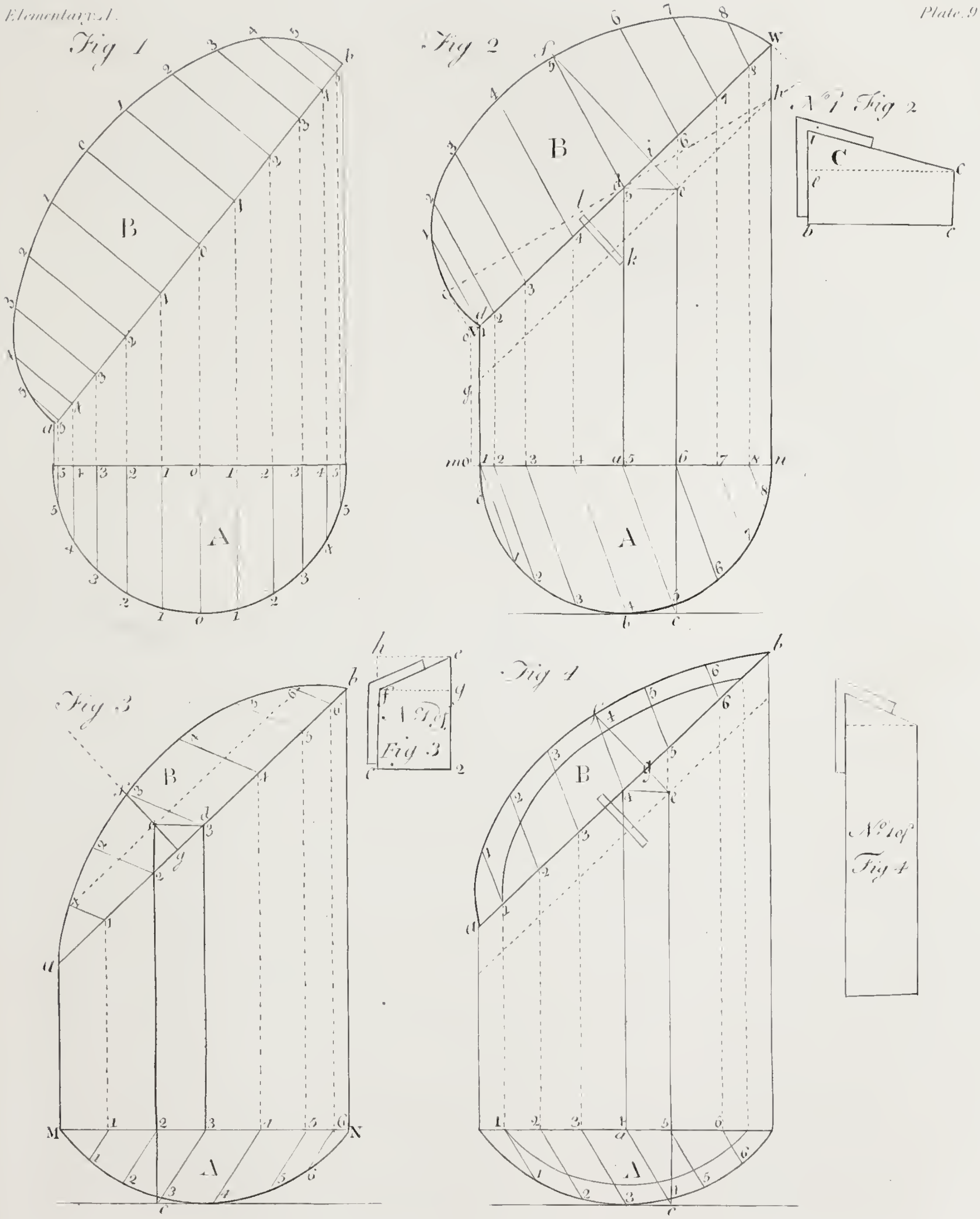

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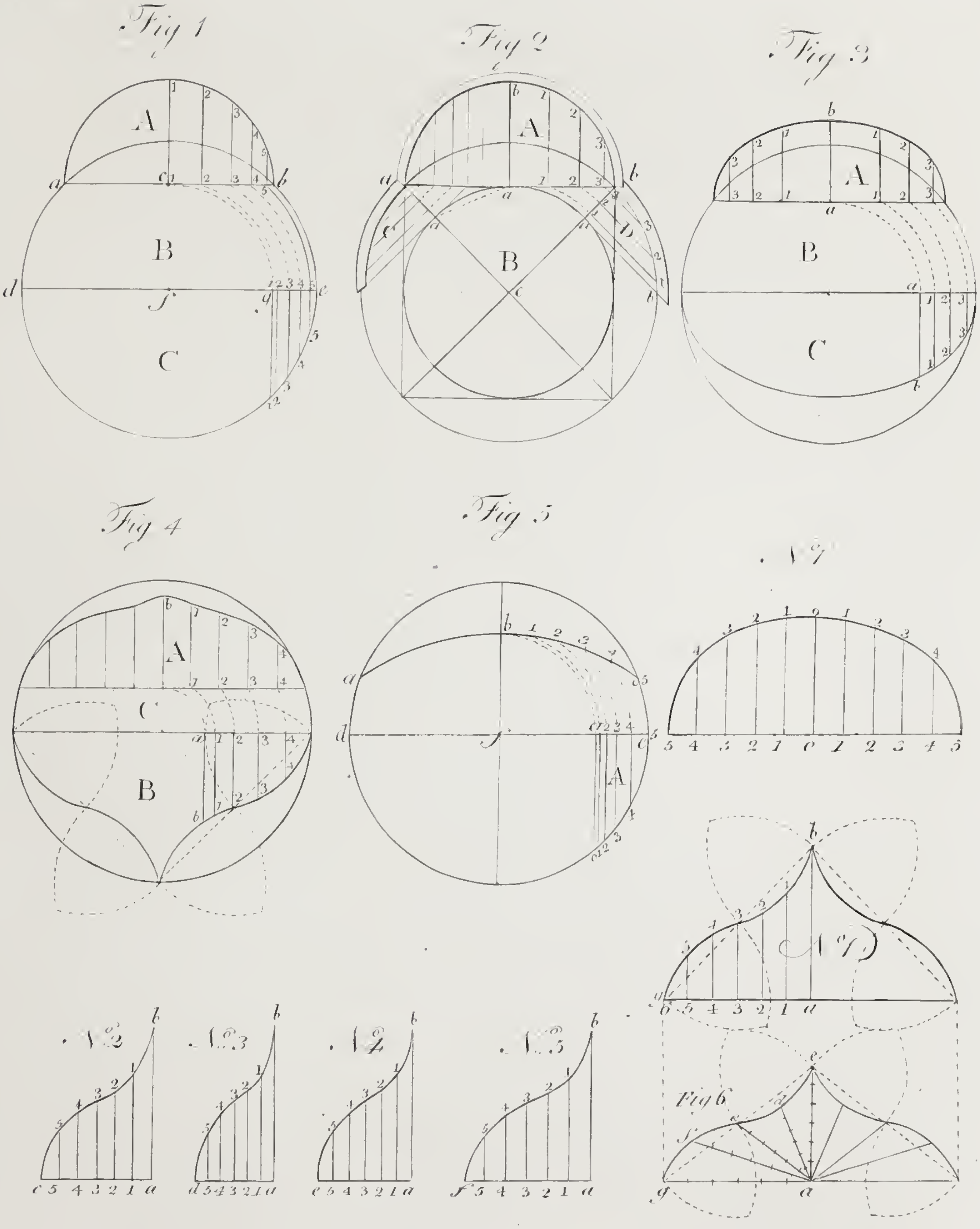
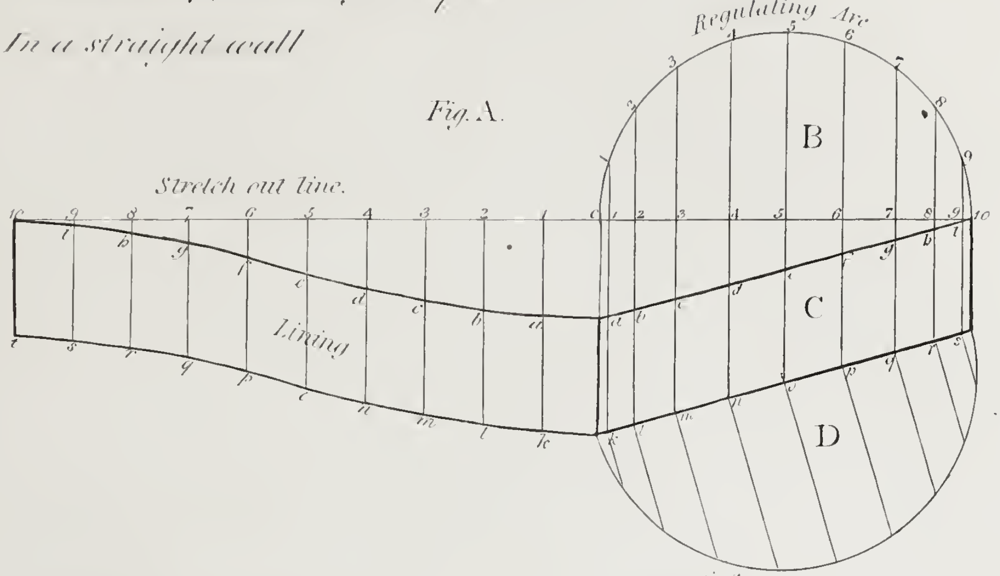


London, John Weale, 1847

Lining for a Parallel soffit cutting oblique

In a straight wall

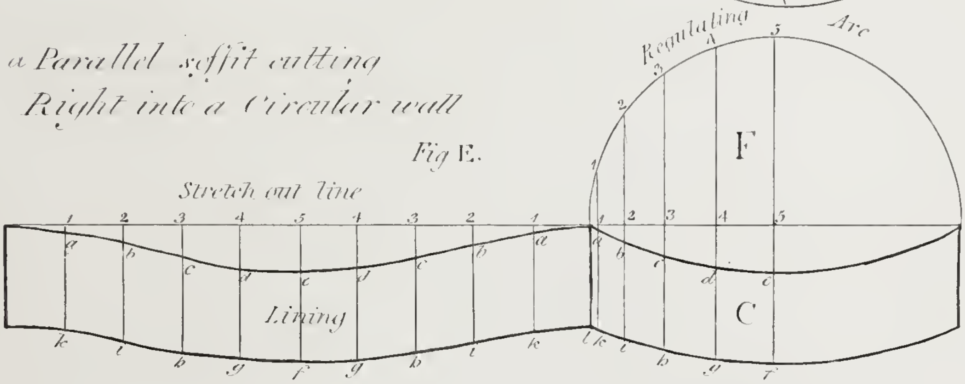
Fig. A.



Lining for a Parallel soffit cutting

Right into a Circular wall

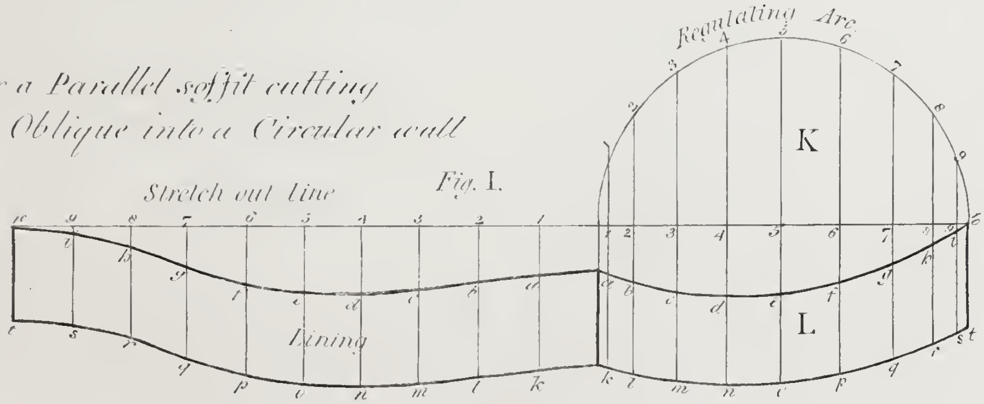
Fig E.



Lining for a Parallel soffit cutting

Oblique into a Circular wall

Fig. I.



Lining for a soffit cutting right into a straight wall Fluing equally all round

Elementary A.

Fig. A.

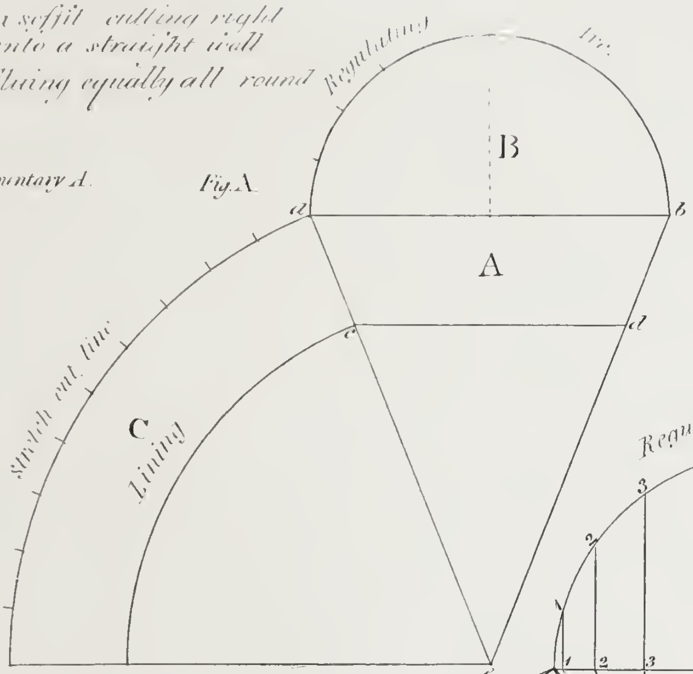
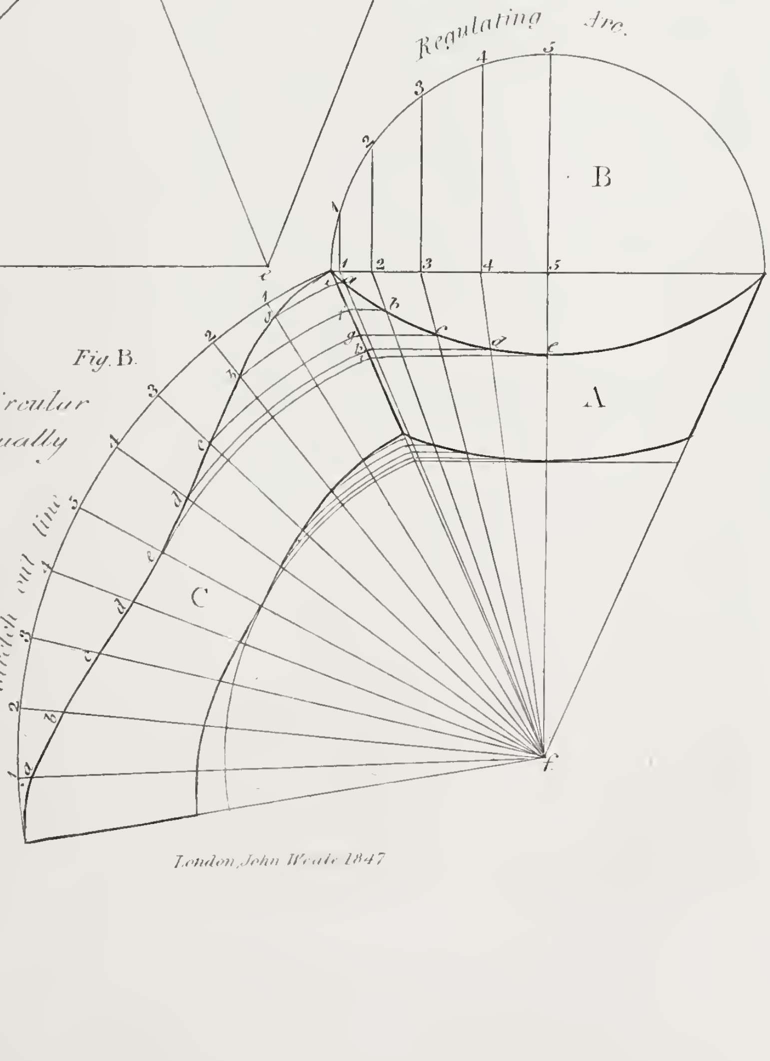
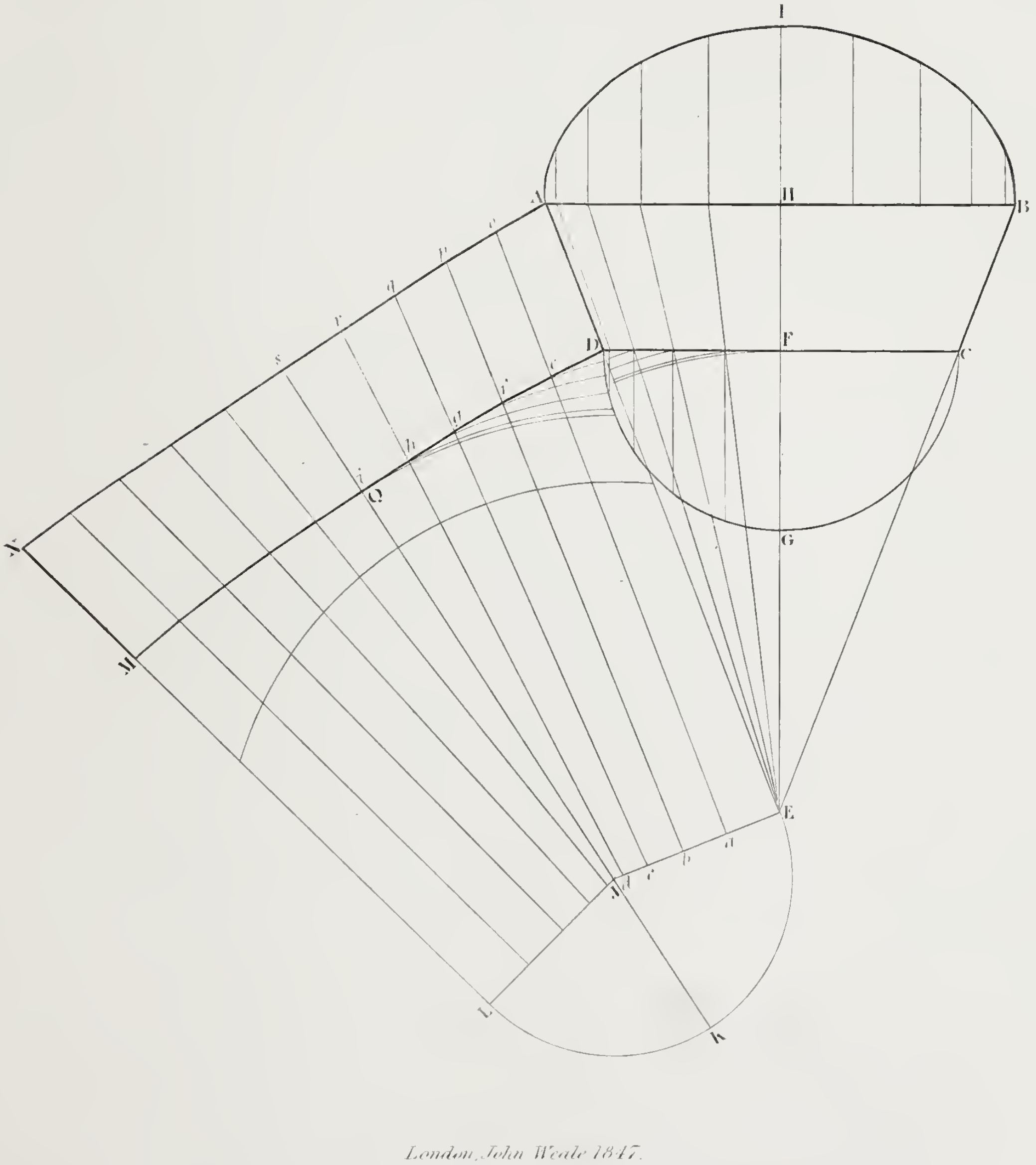


Fig. B.

Lining for a soffit in a Circular Wall fluing equally all round



London, John Weale 1847



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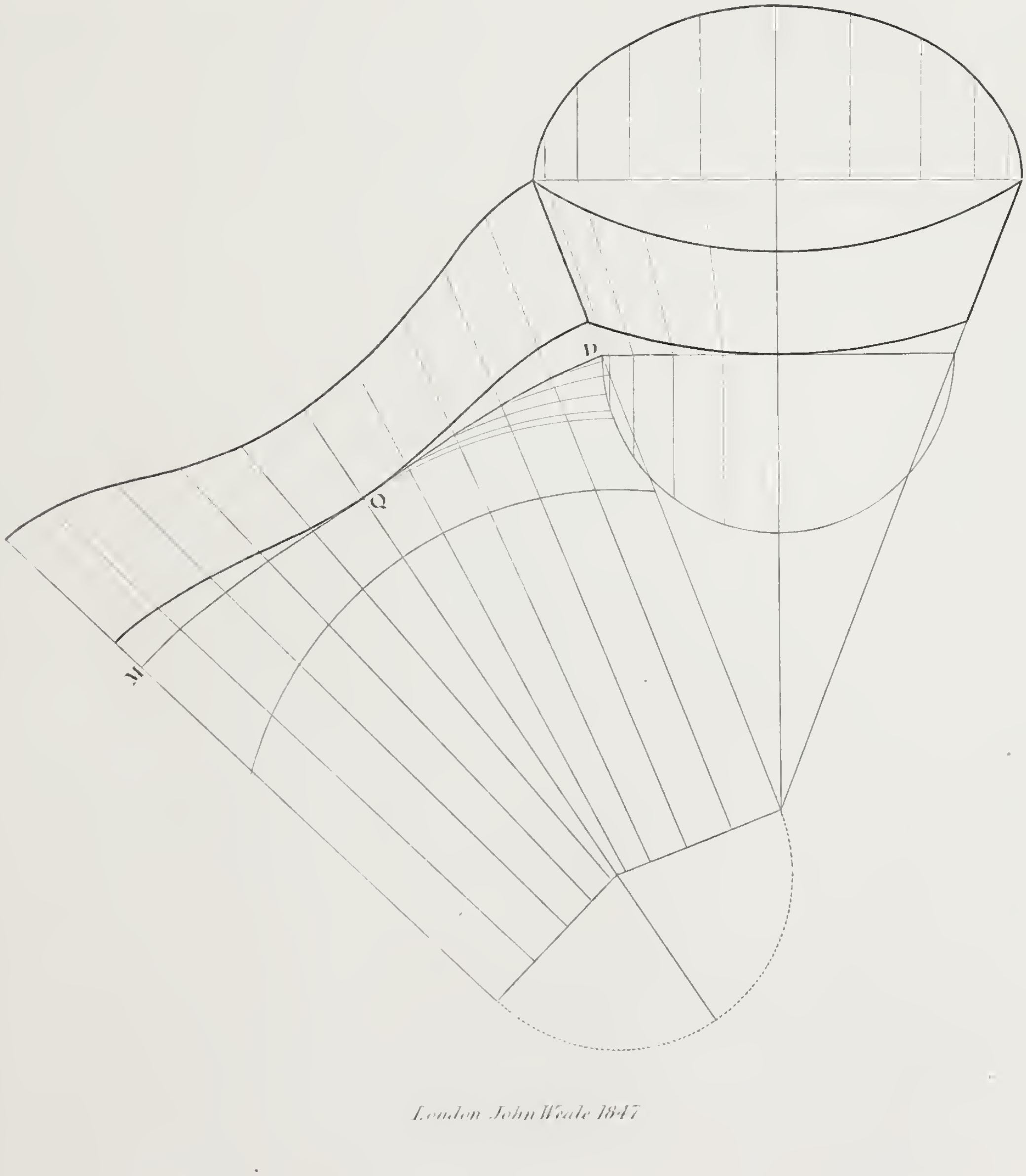


London. John Weale 1847

Fig A

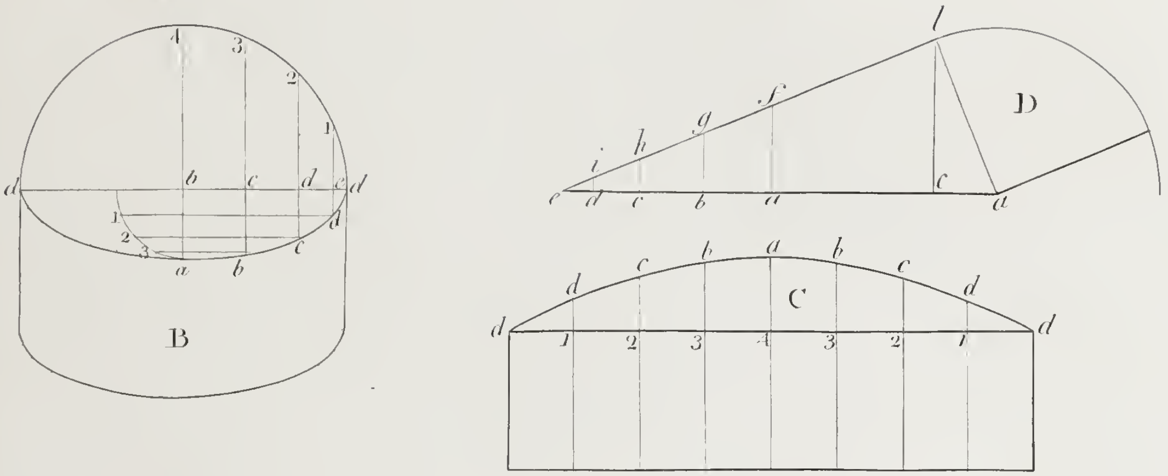
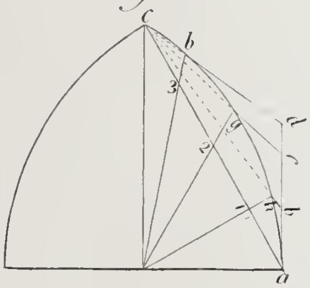
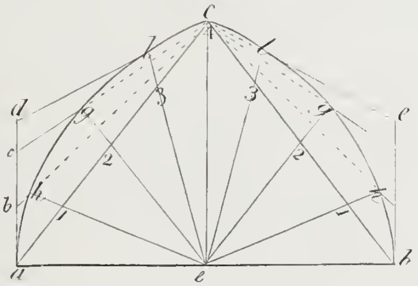


Fig E



N.º 2



N.º 3

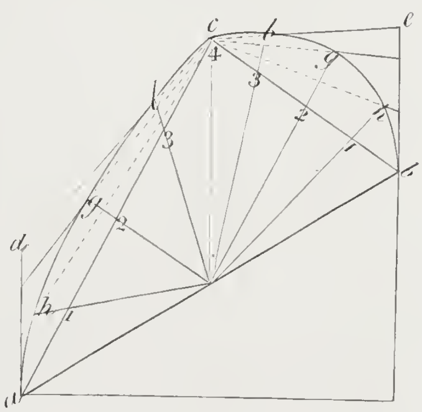
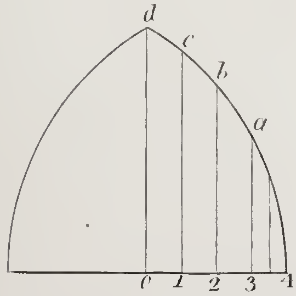


Fig F



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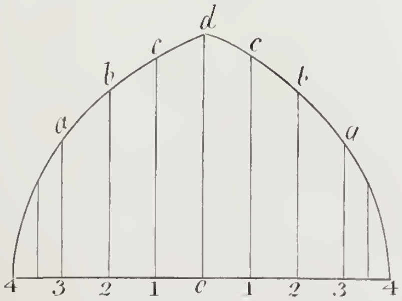

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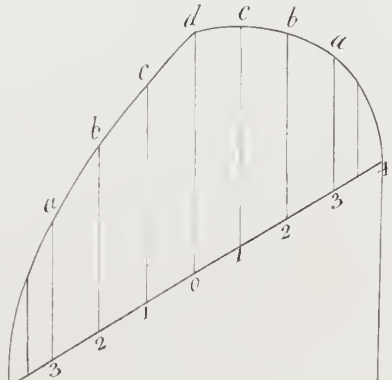

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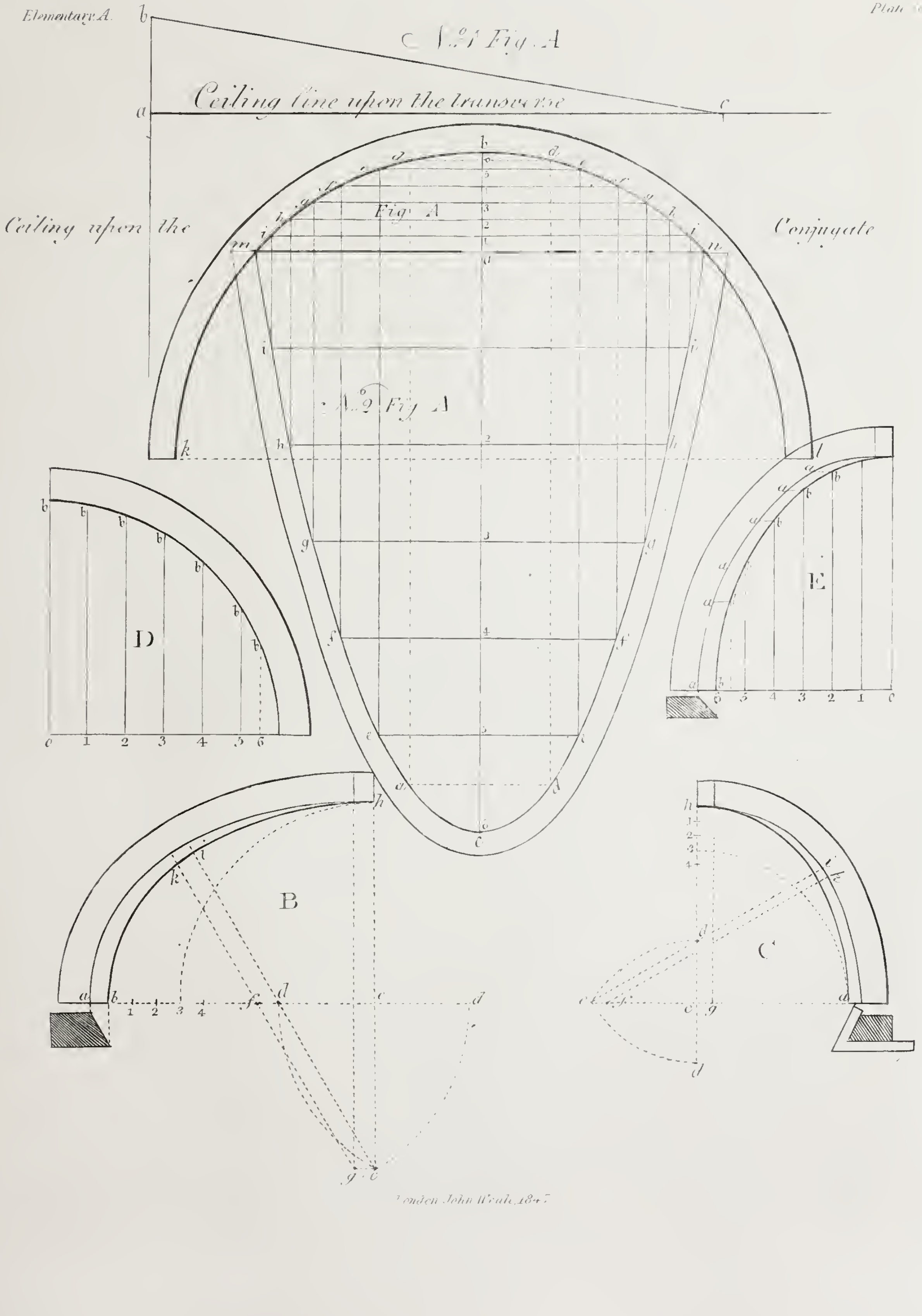
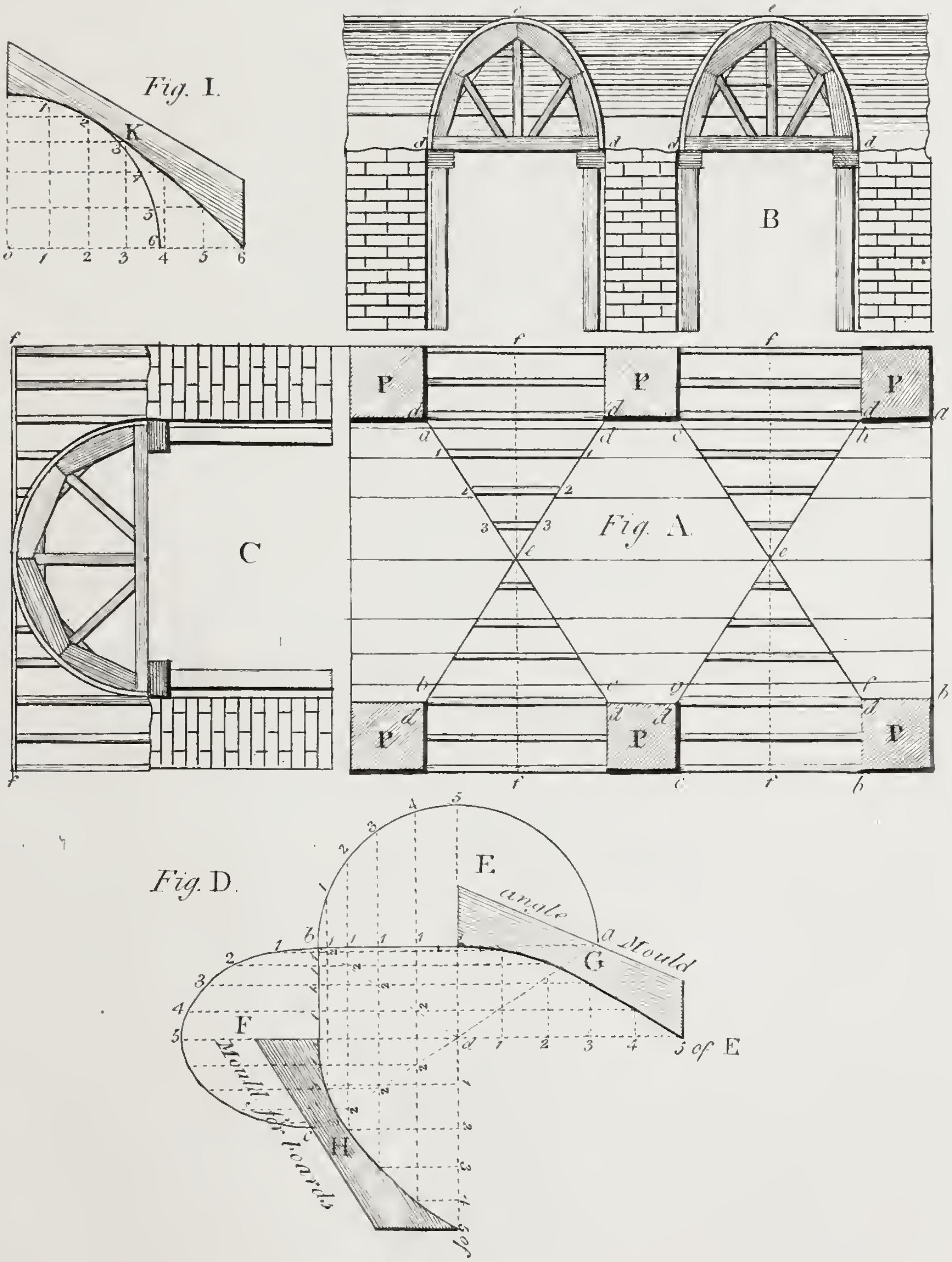


London John Weale 1847



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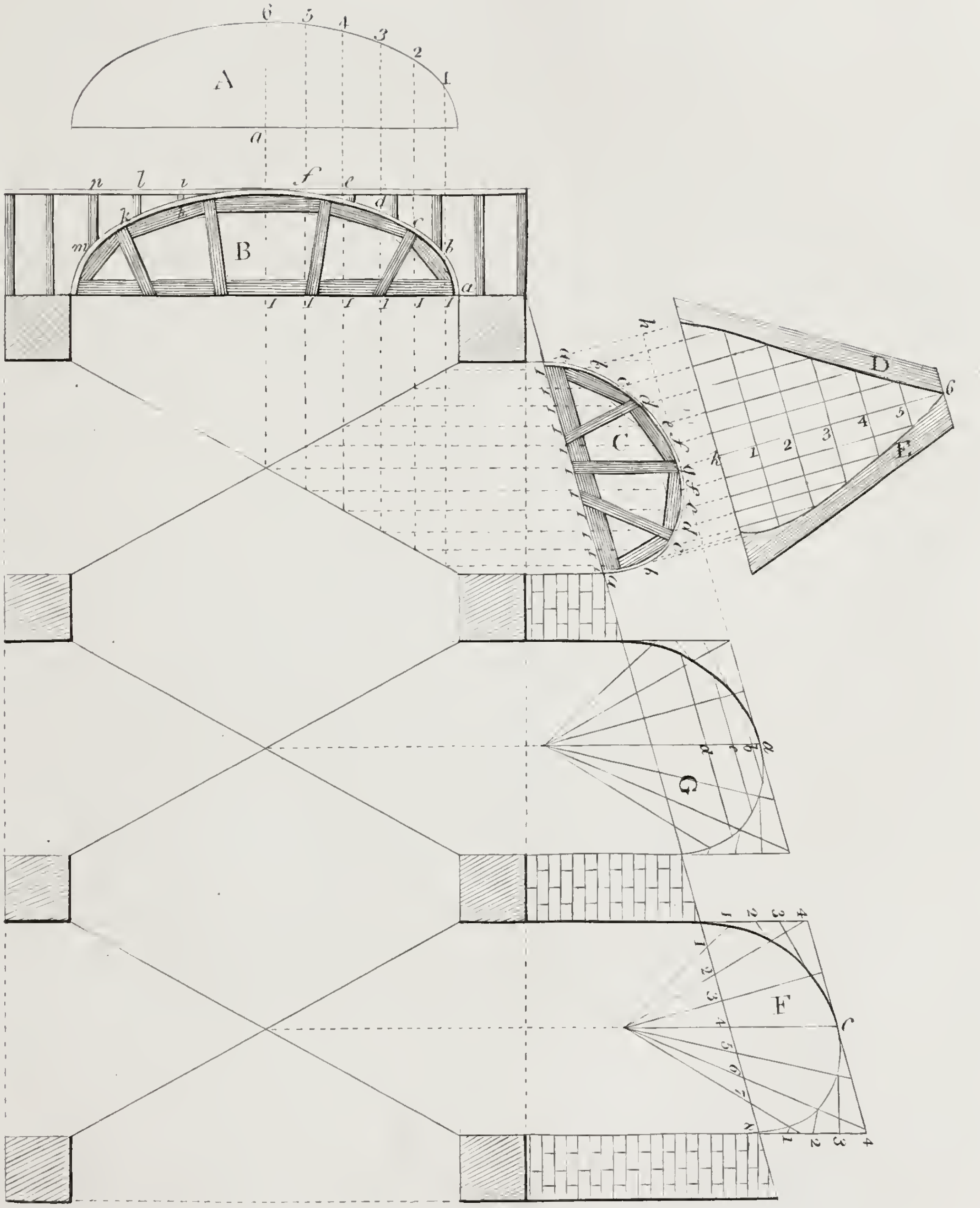

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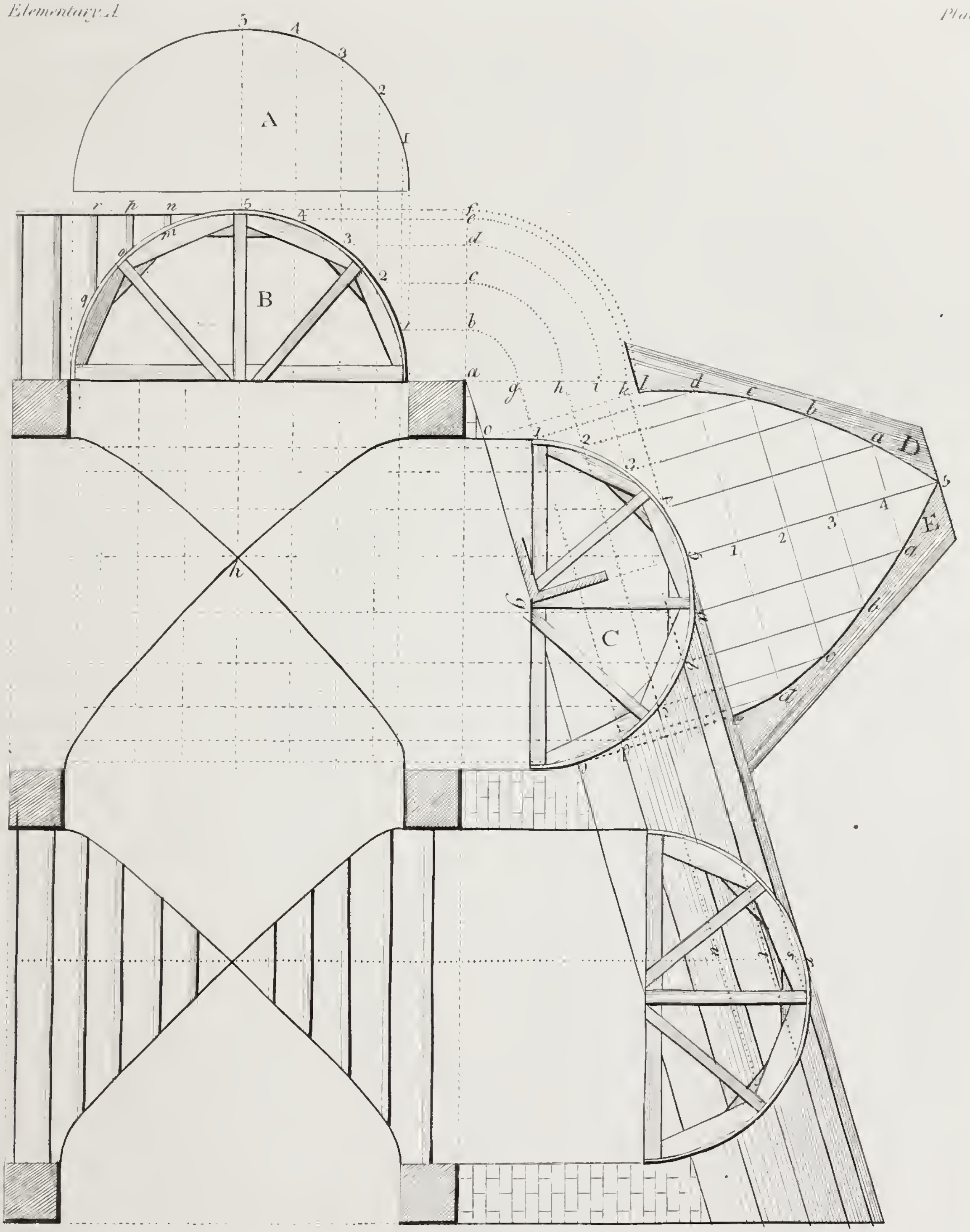

London, John Weale 1847.

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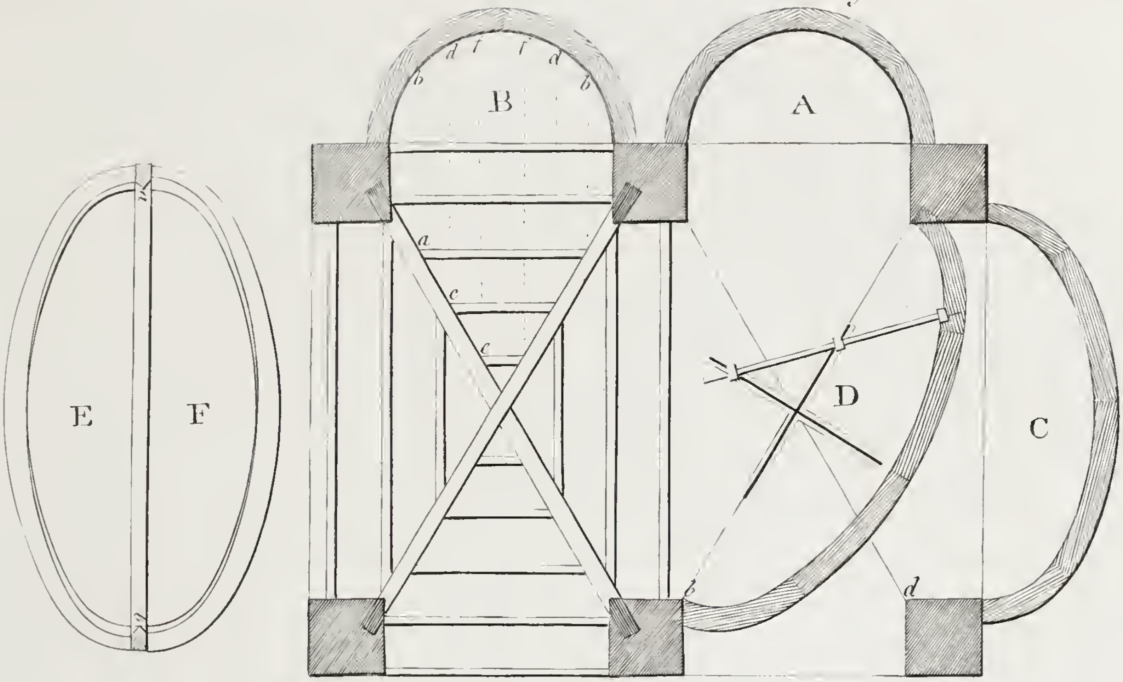

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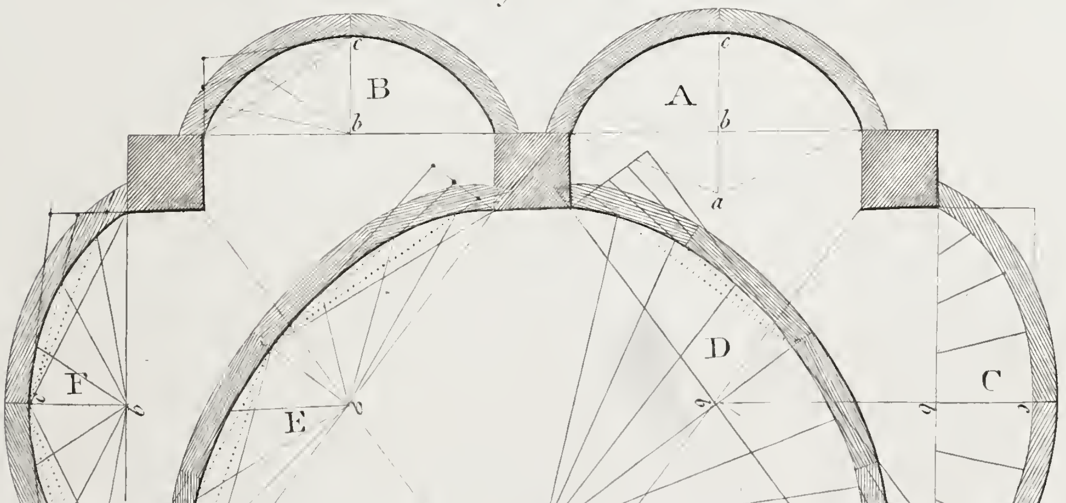

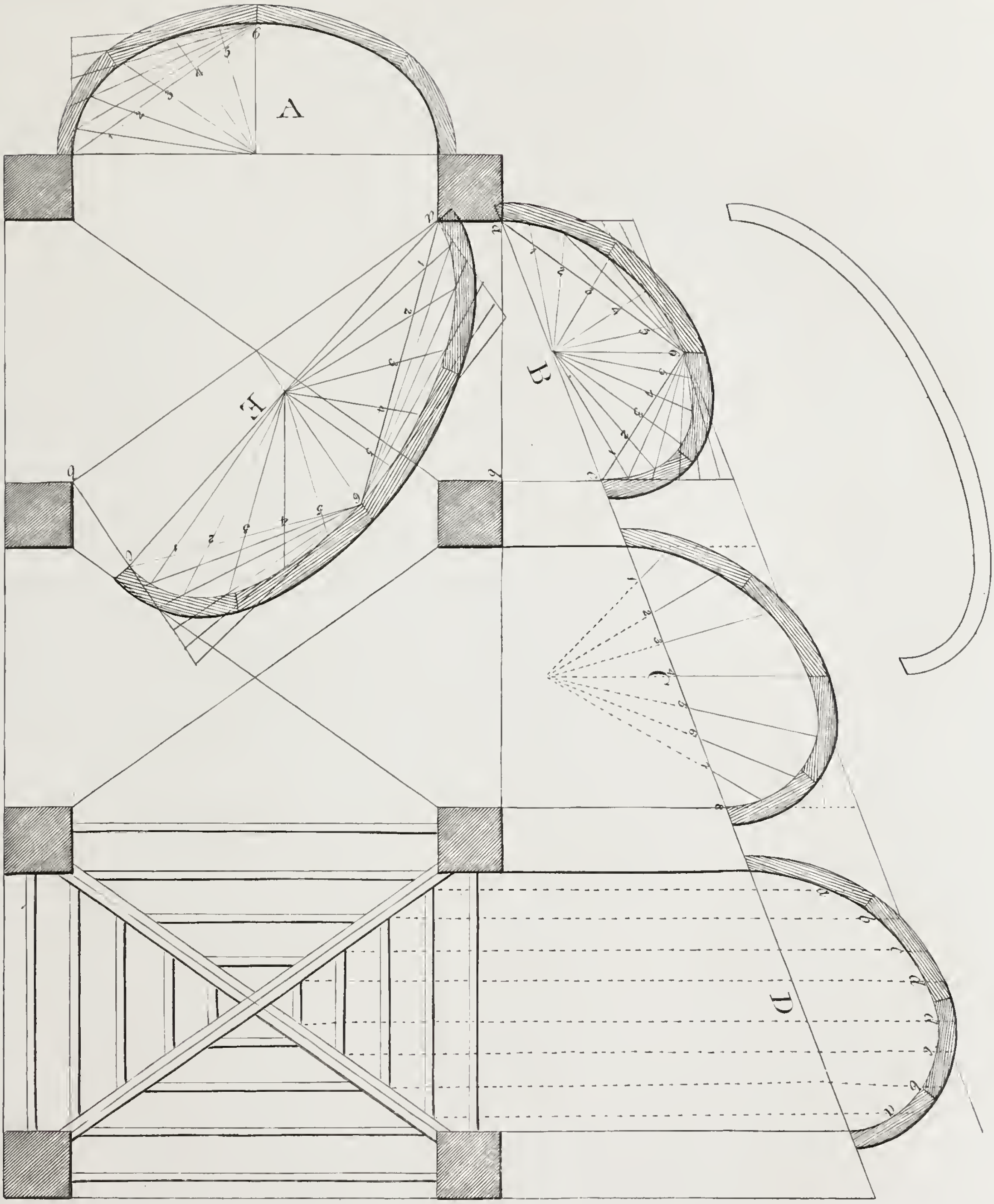
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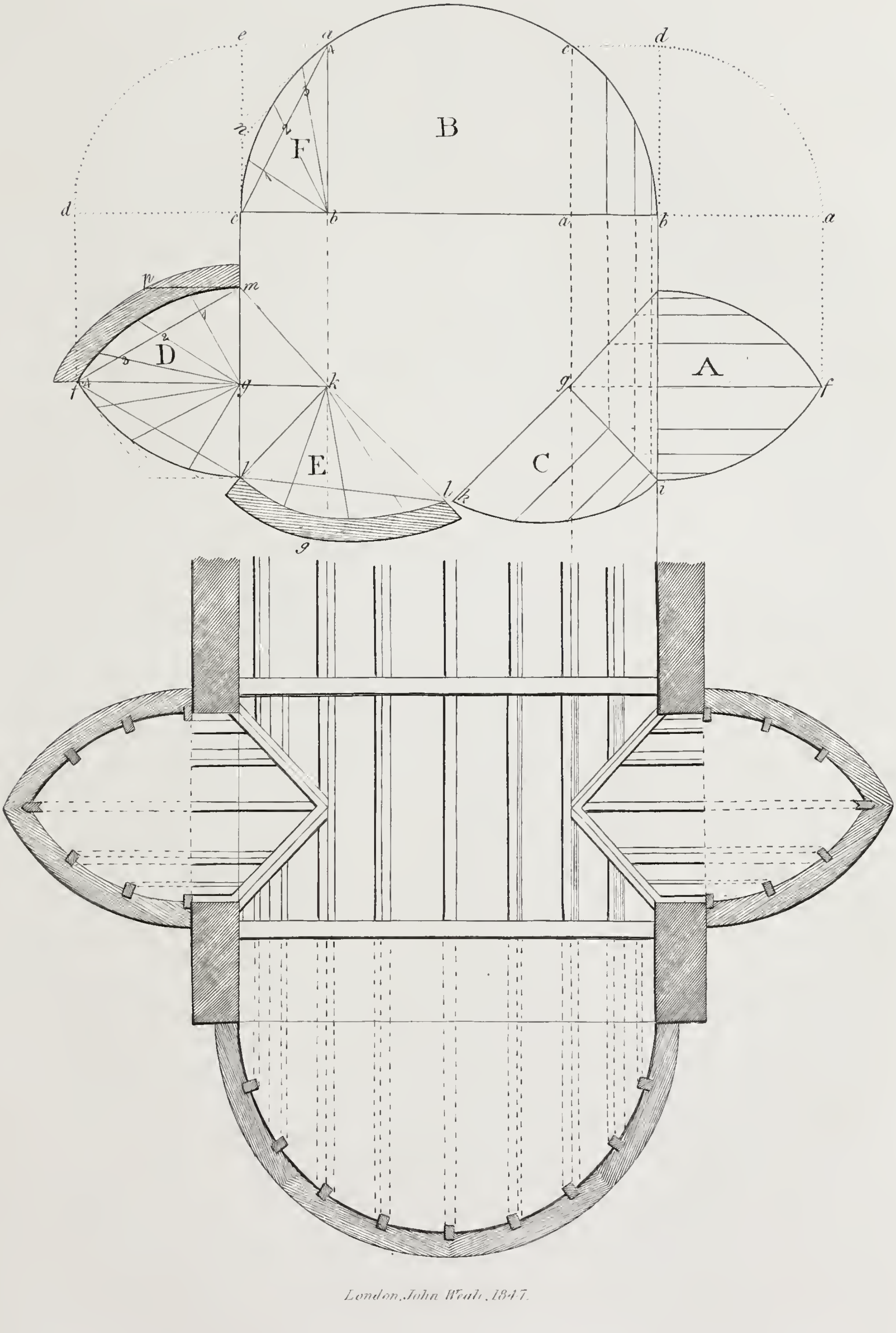
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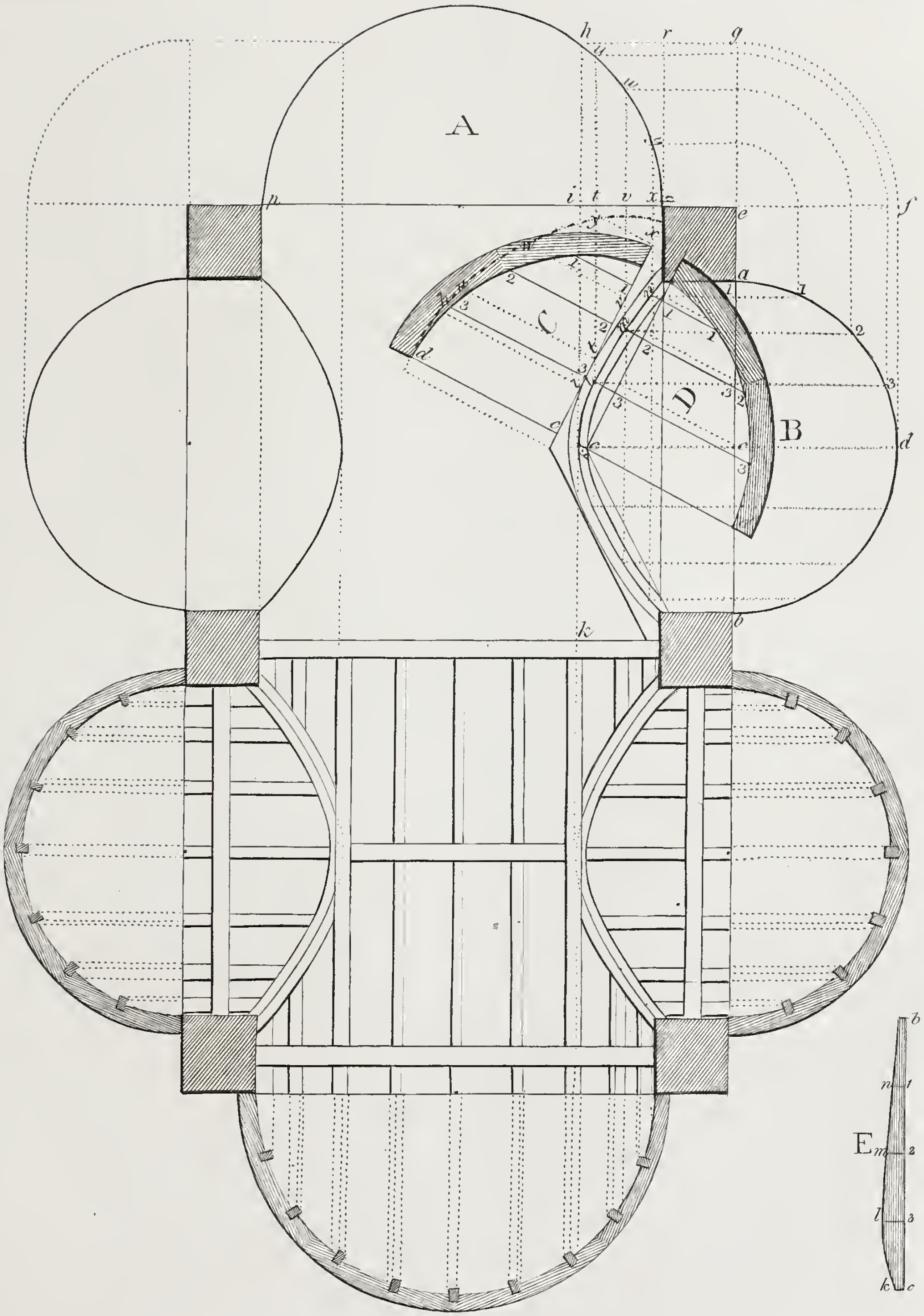

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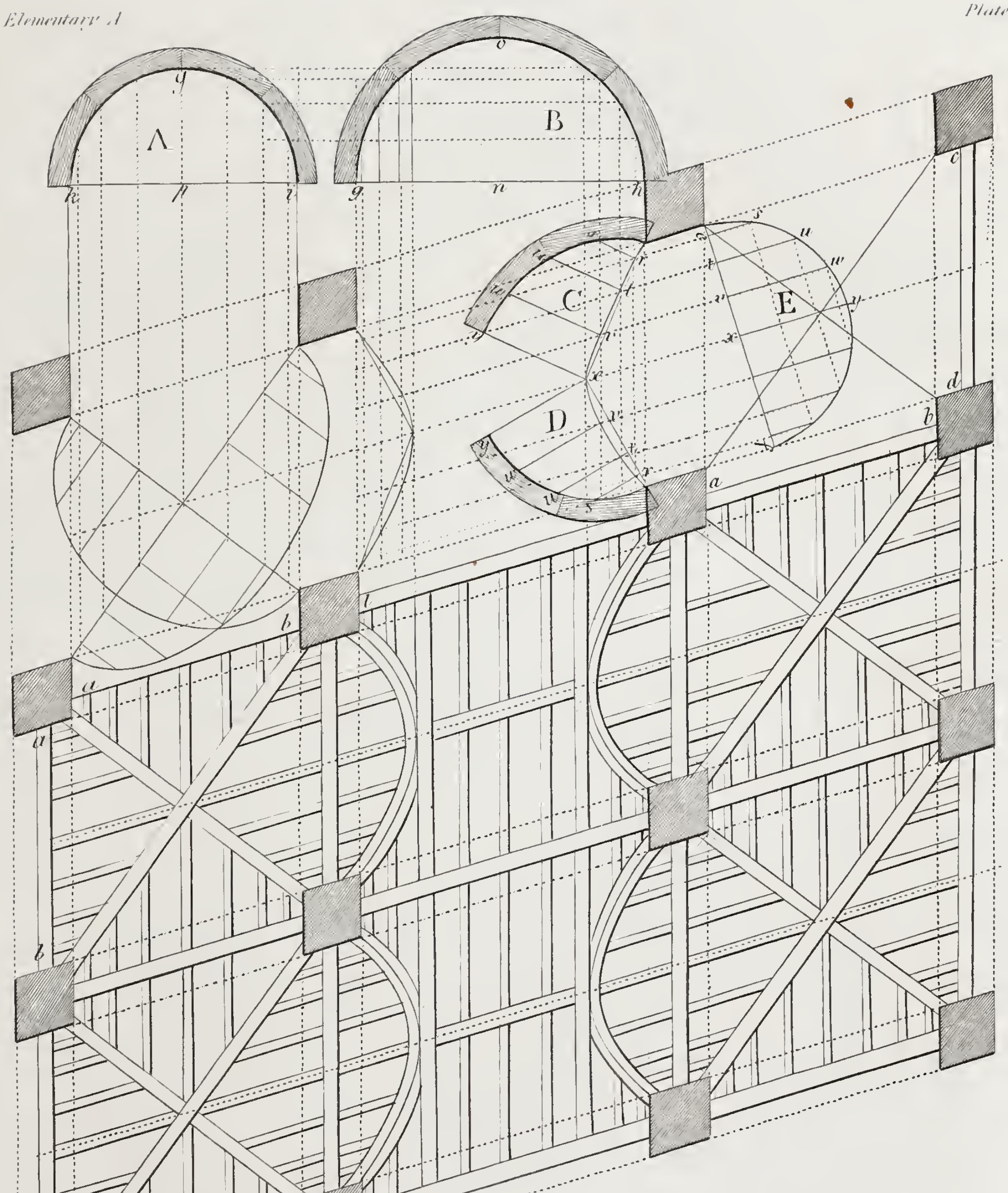

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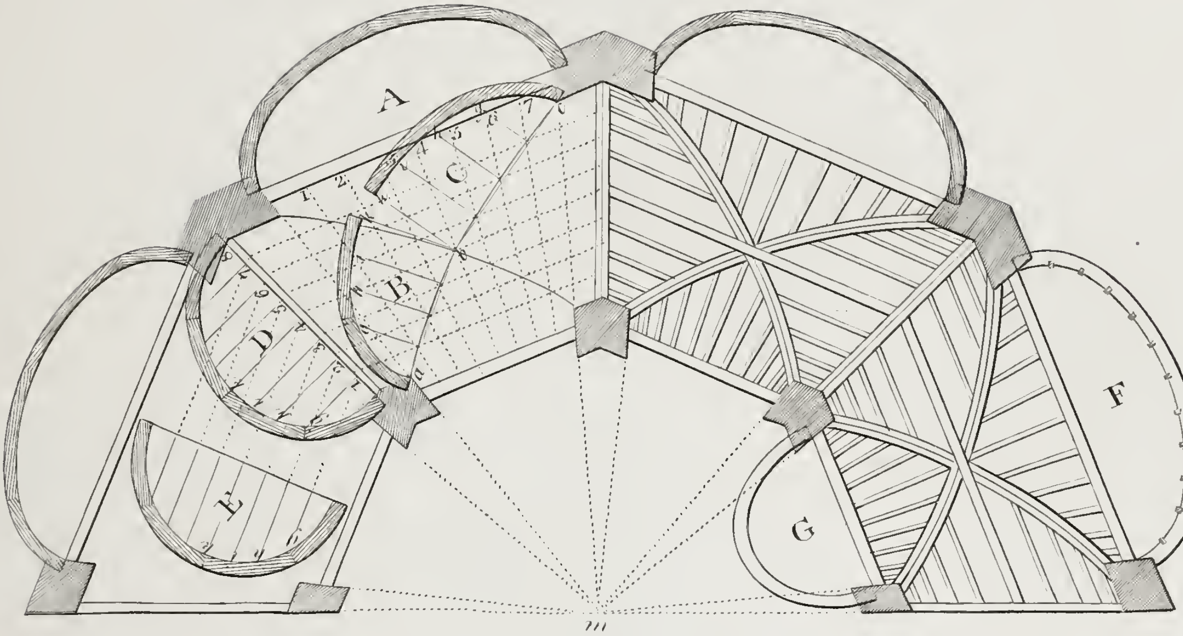

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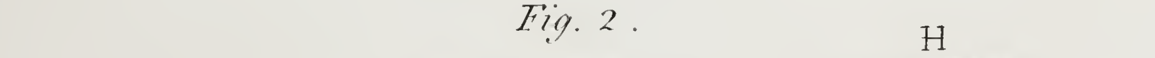

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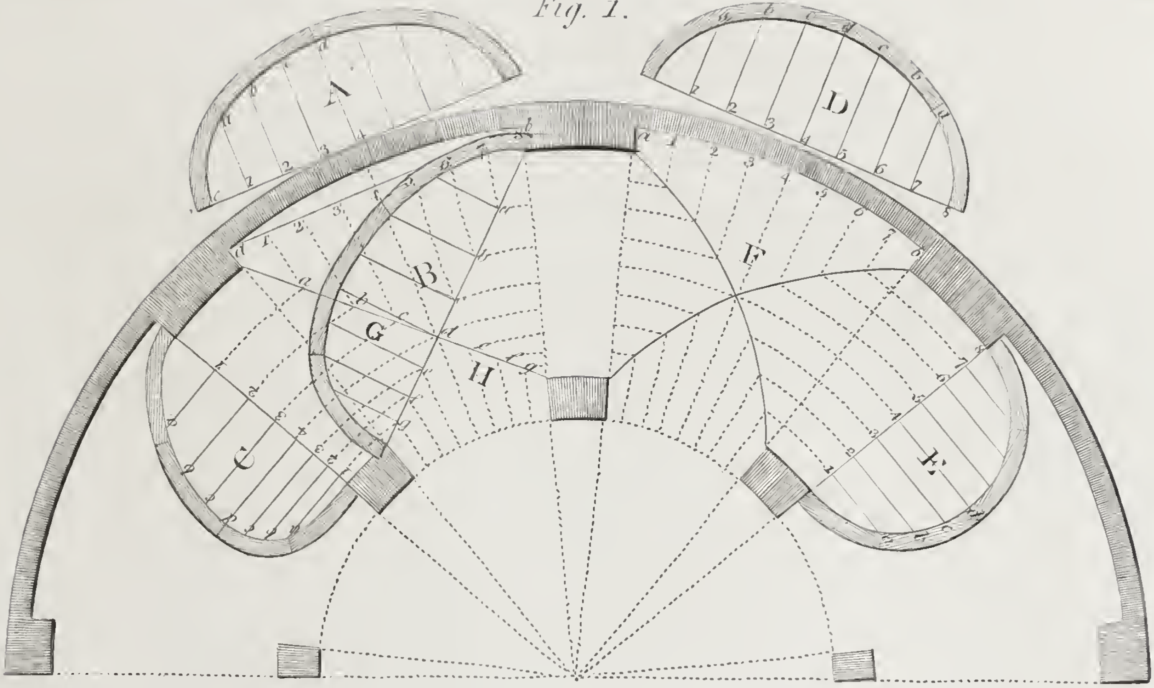

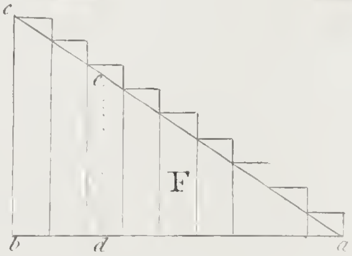

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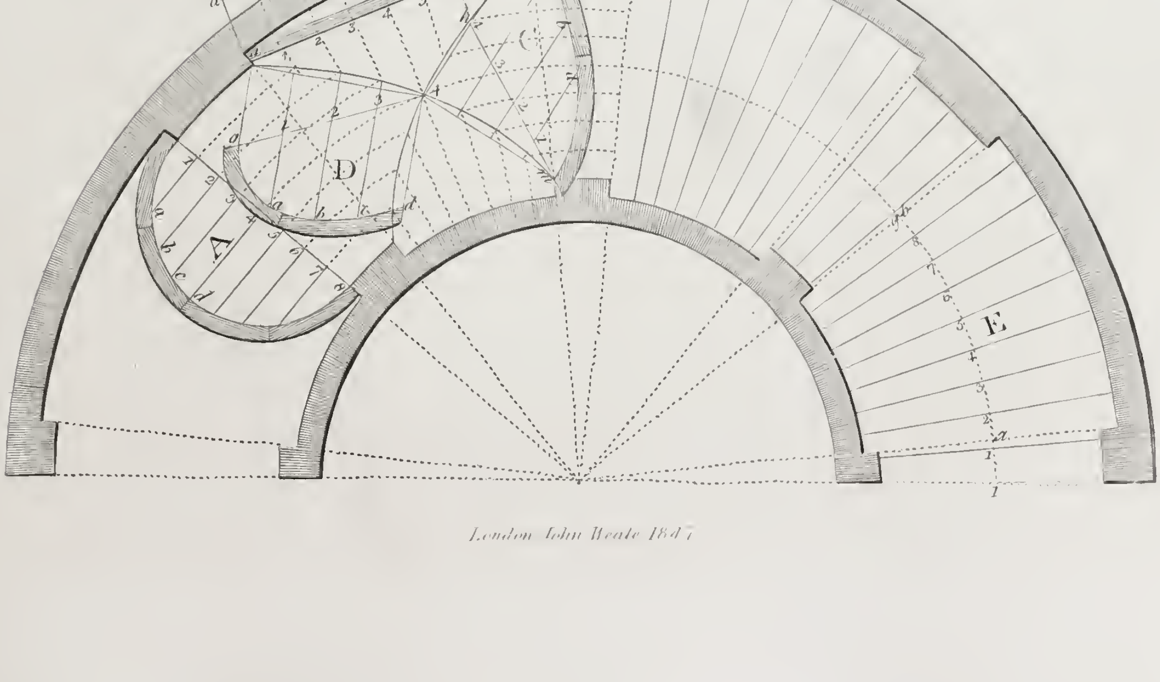

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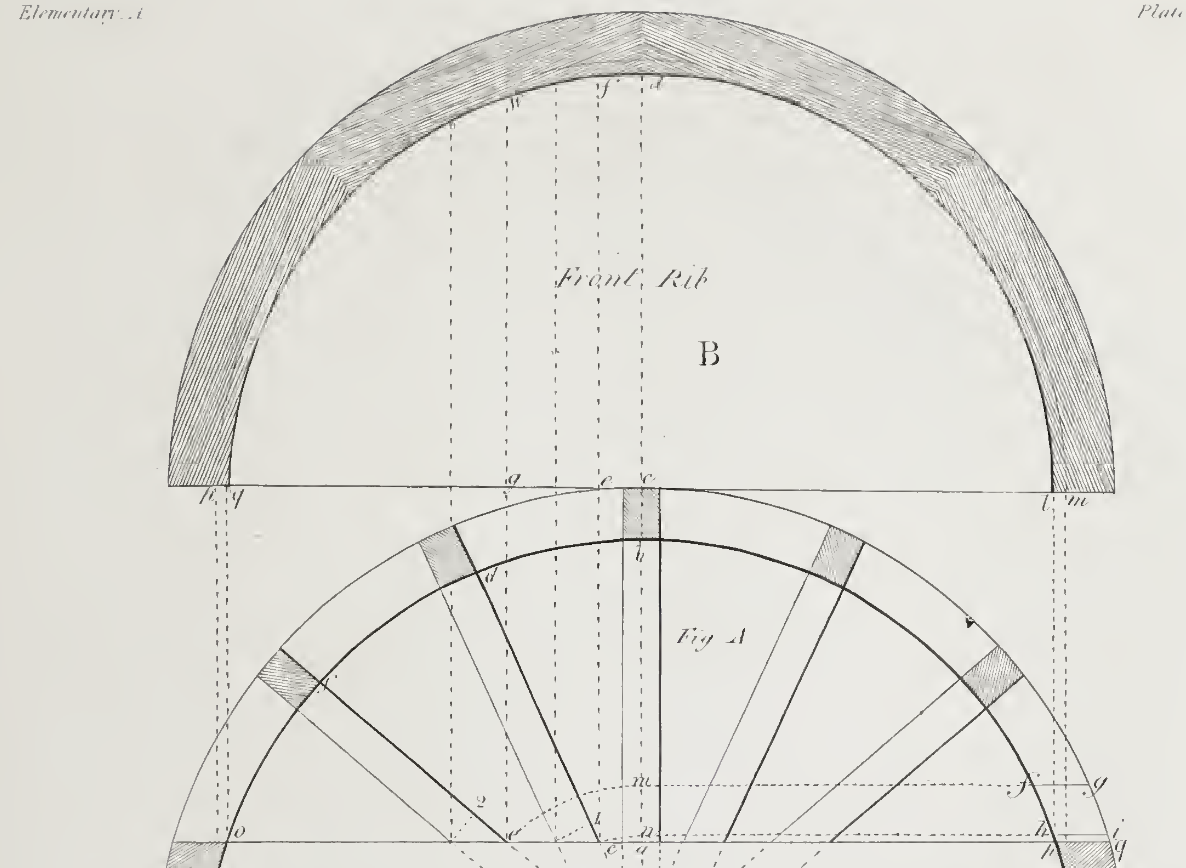

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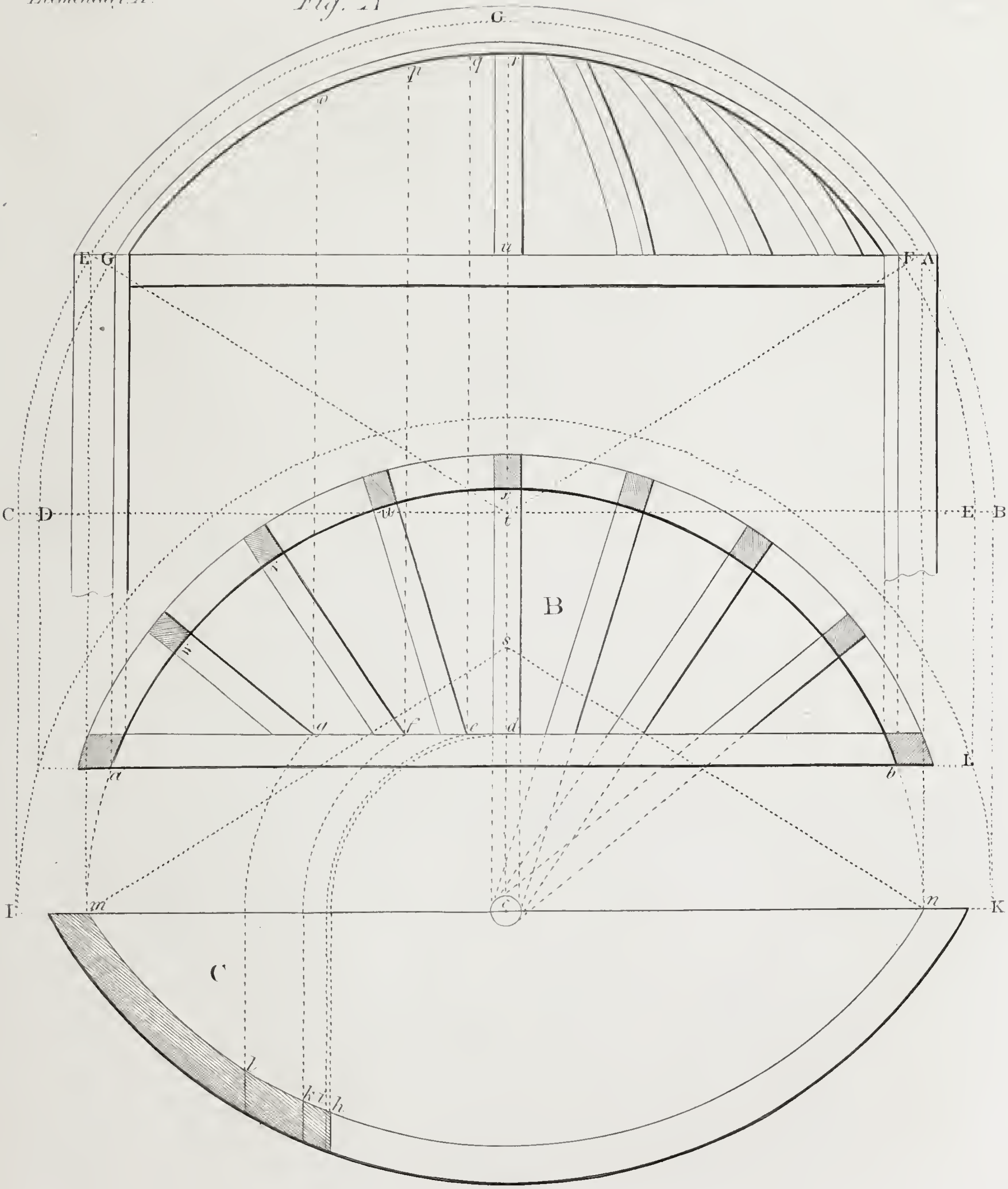

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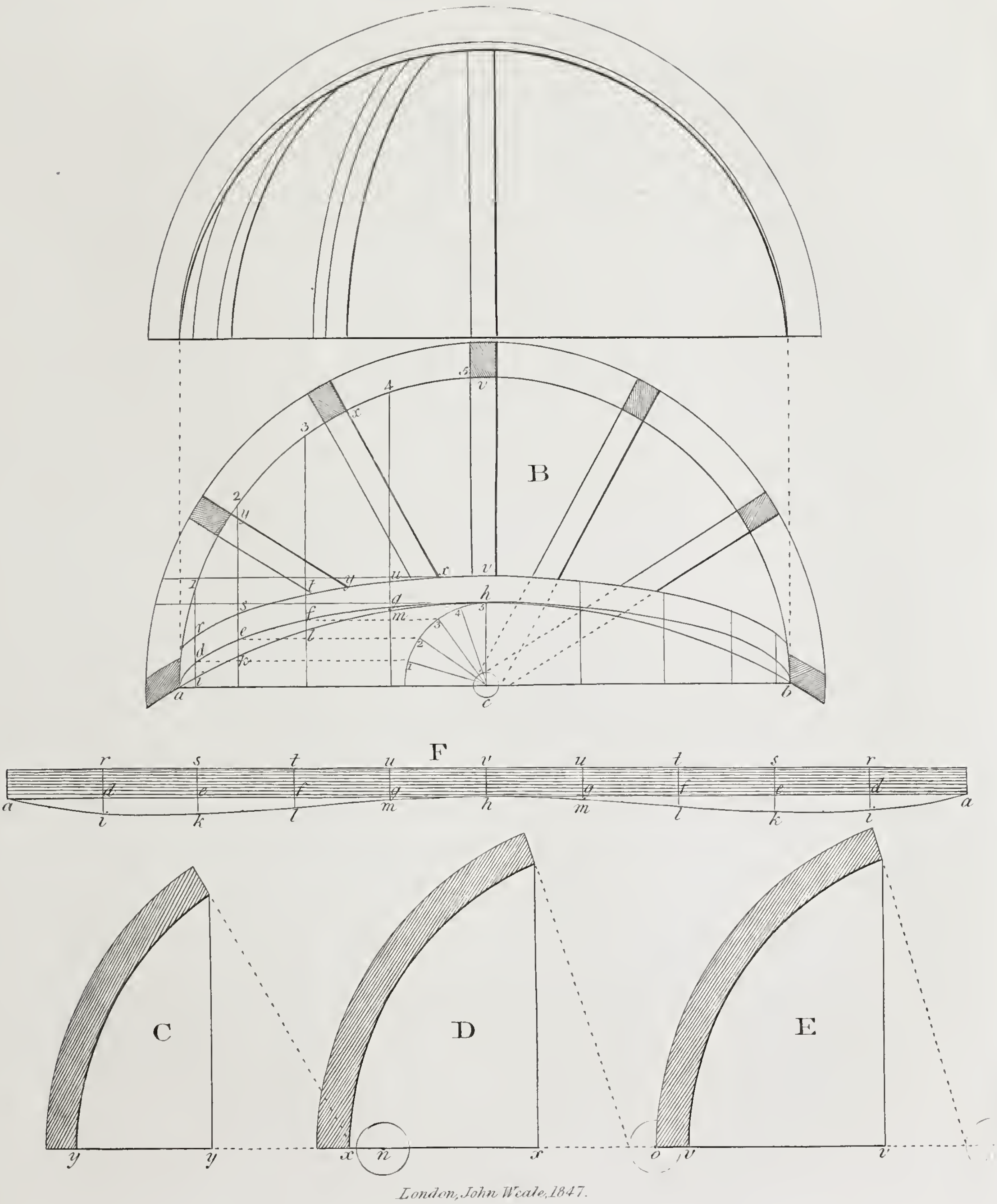
Fig. A



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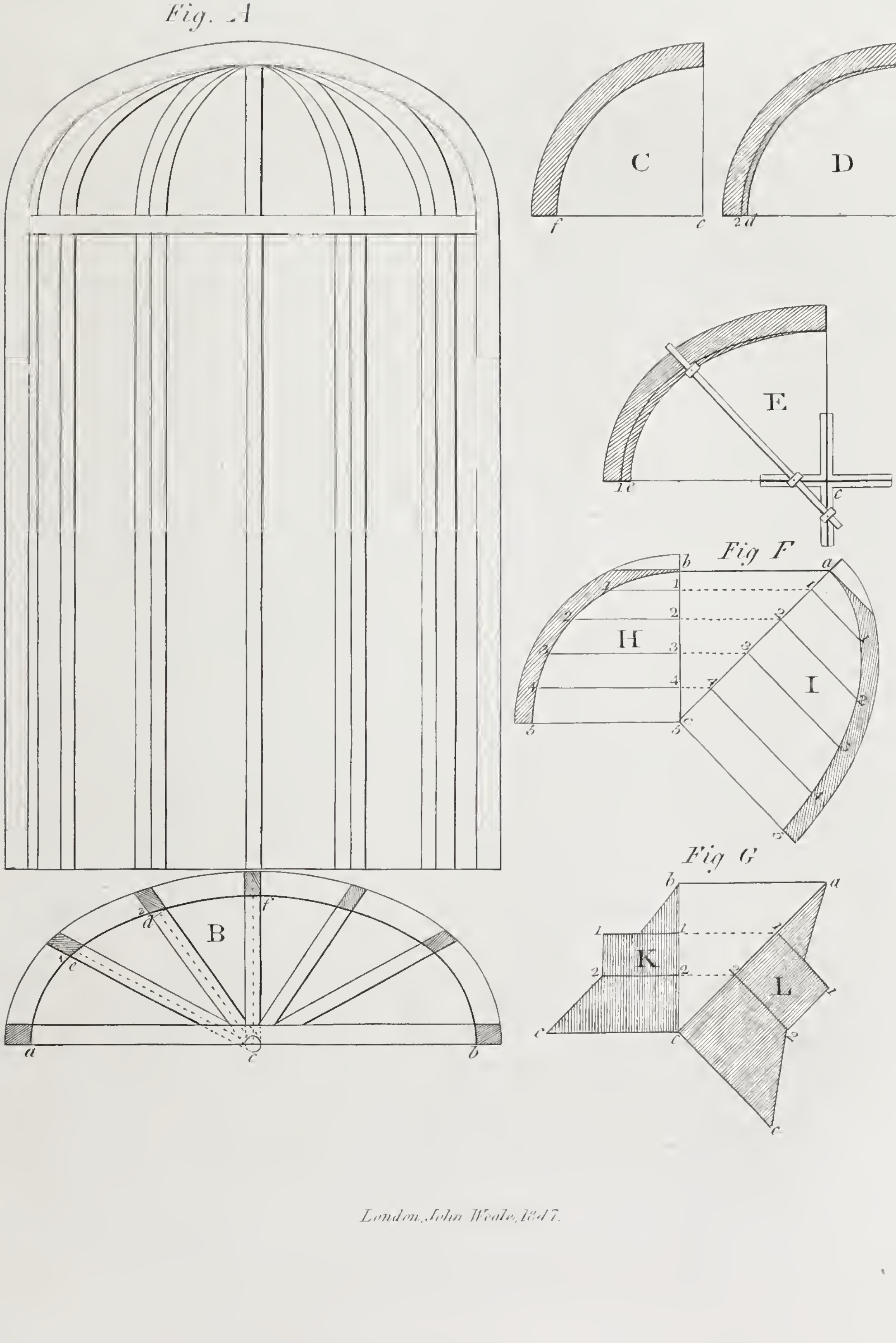

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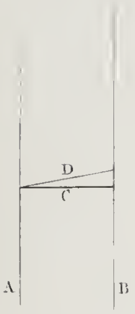

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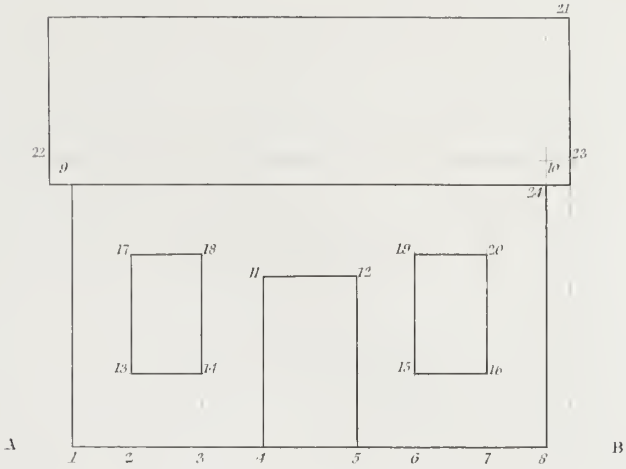

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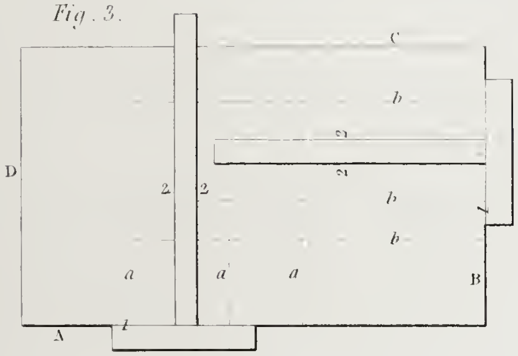

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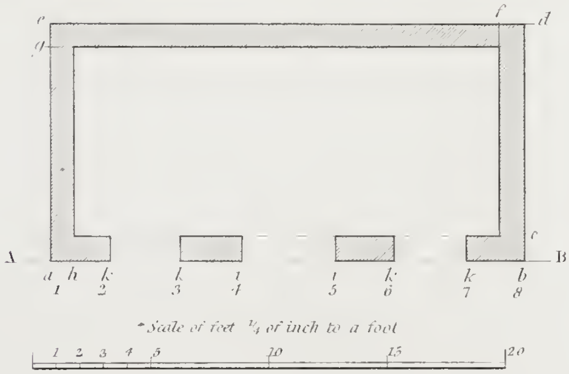
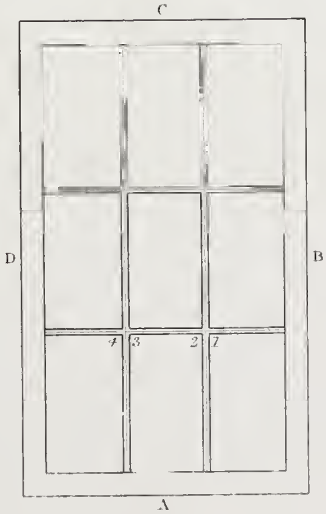


Fig. 4

Fig. 10.



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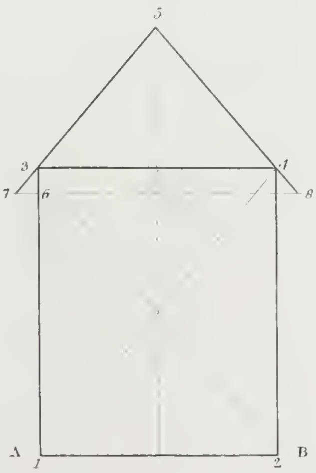

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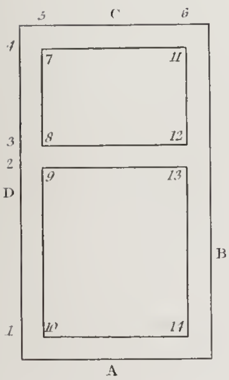

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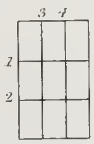

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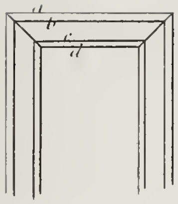

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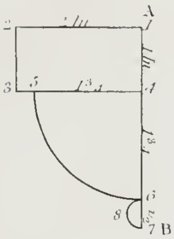

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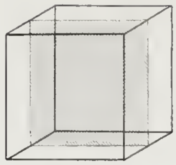

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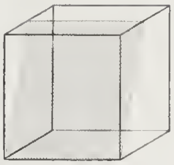


Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

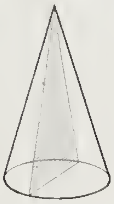


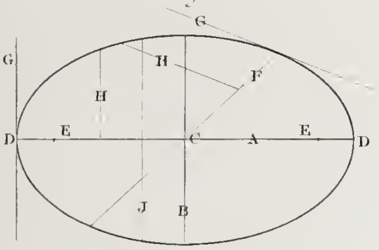
Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.



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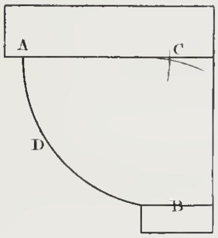

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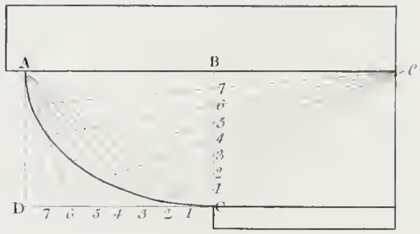

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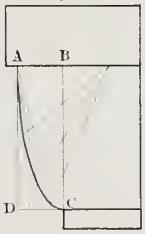

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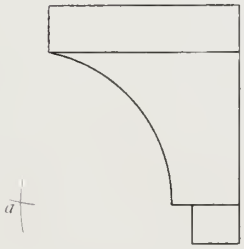

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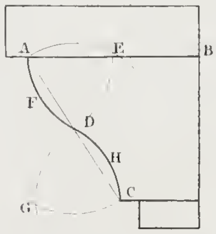

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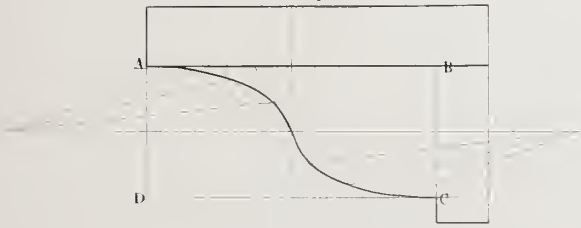

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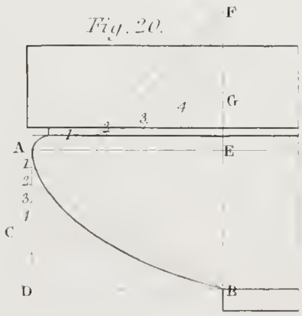

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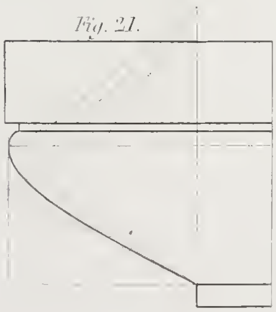

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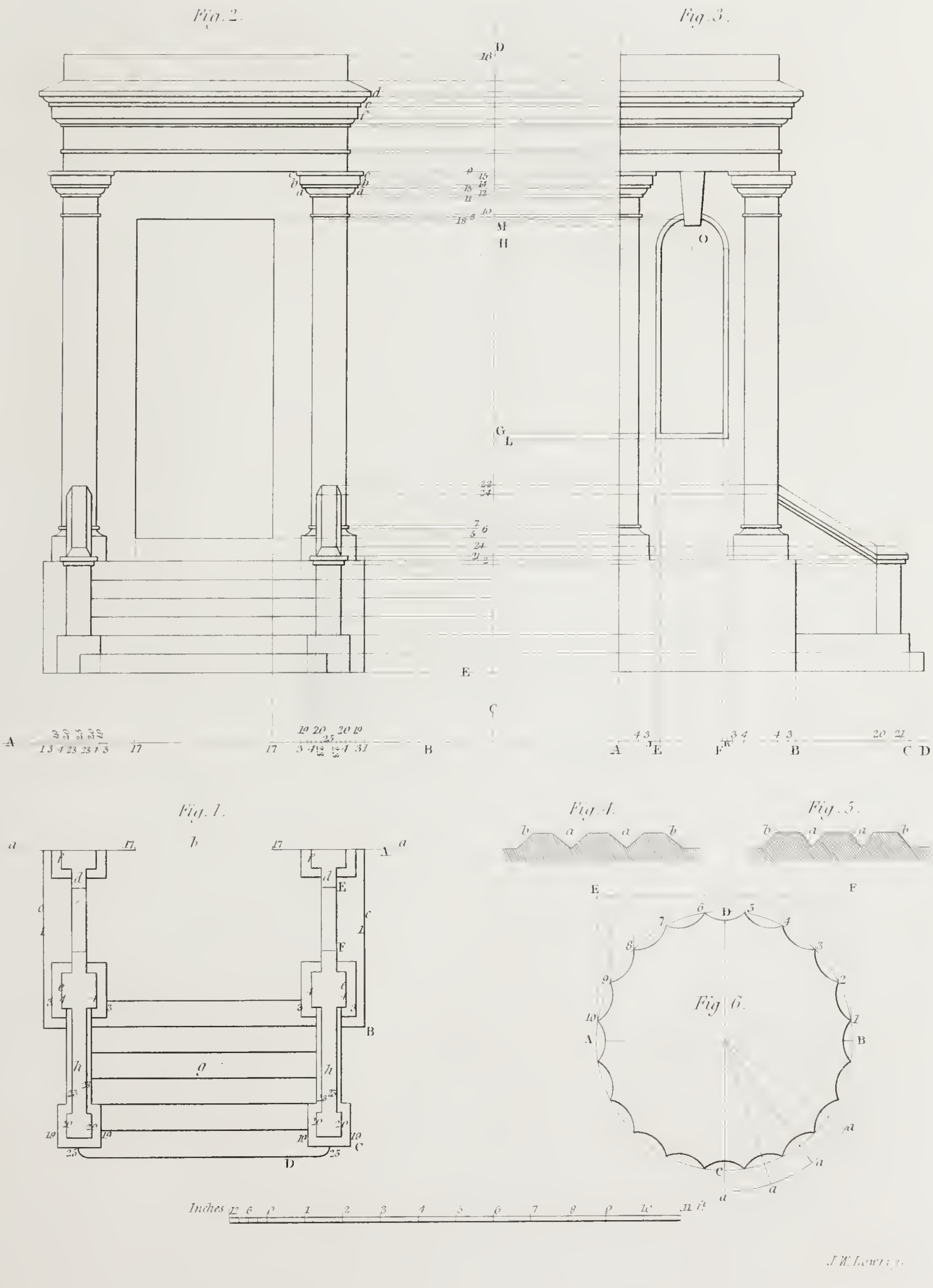
PRACTICAL RULES ON DRAWING PL.3.



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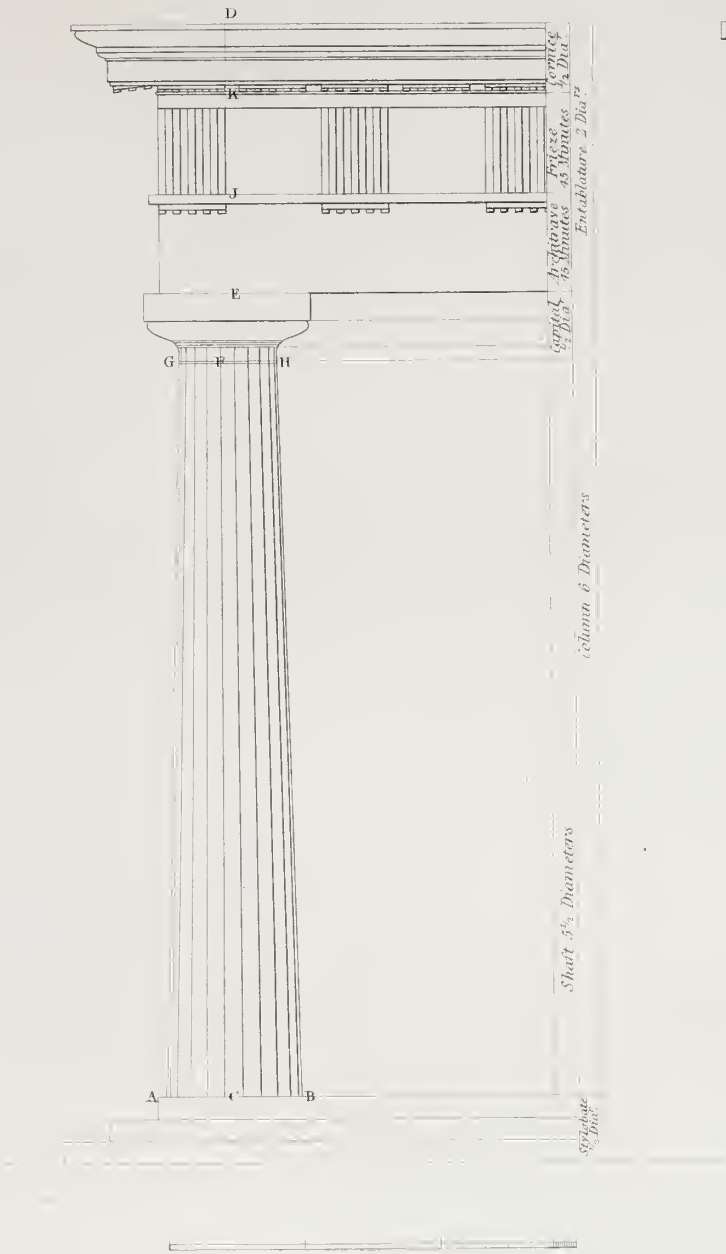
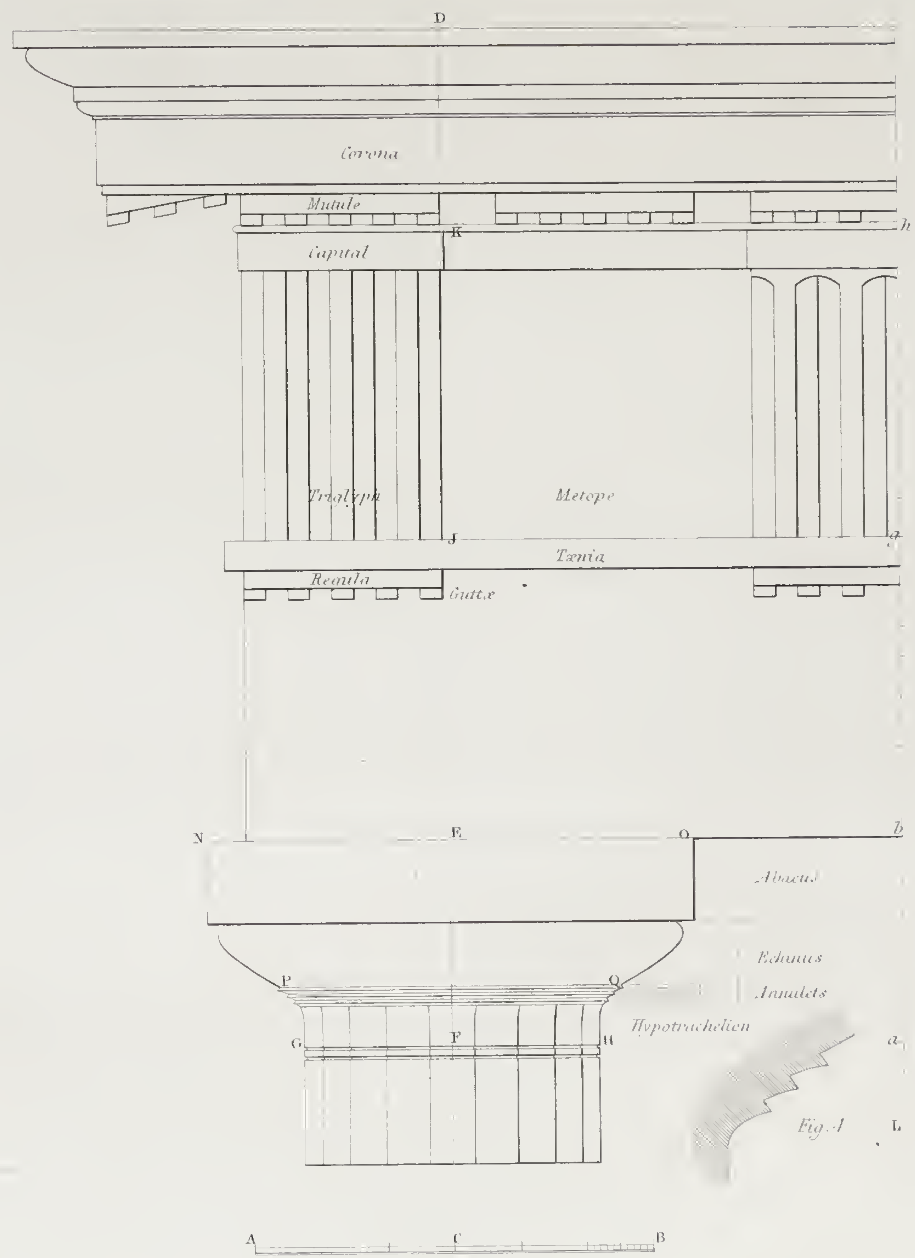


Fig 2

Fig 3



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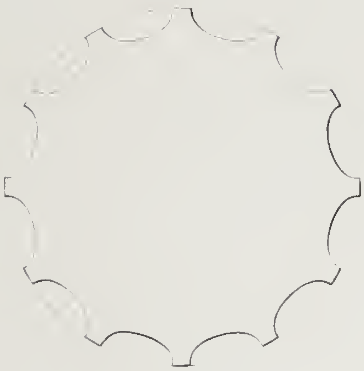

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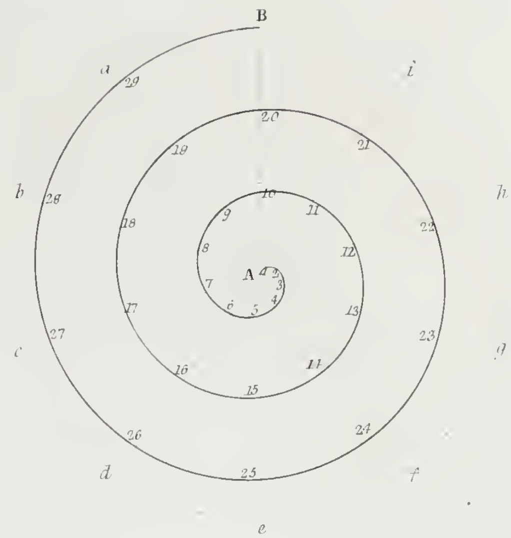

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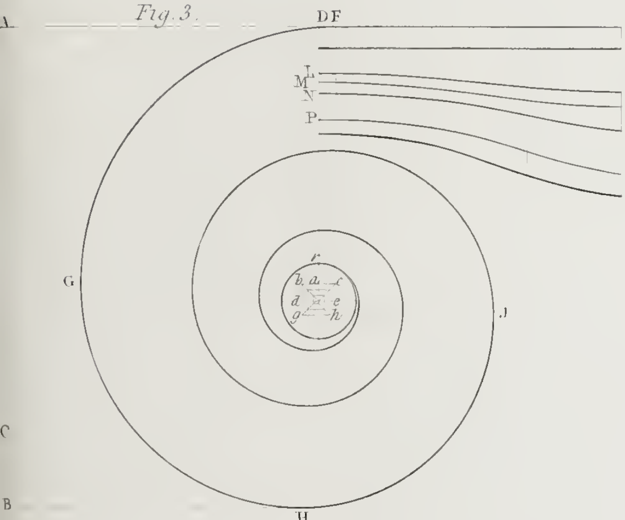

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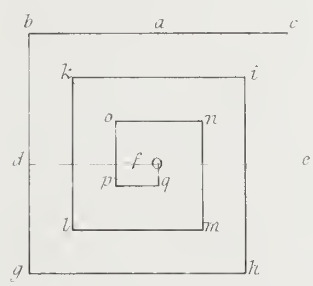

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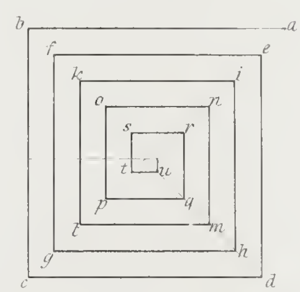

Fig. 8

Fig. 6.

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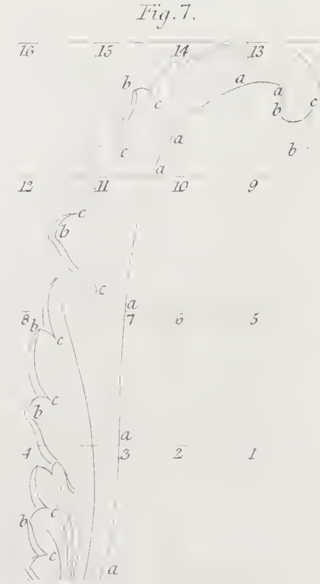

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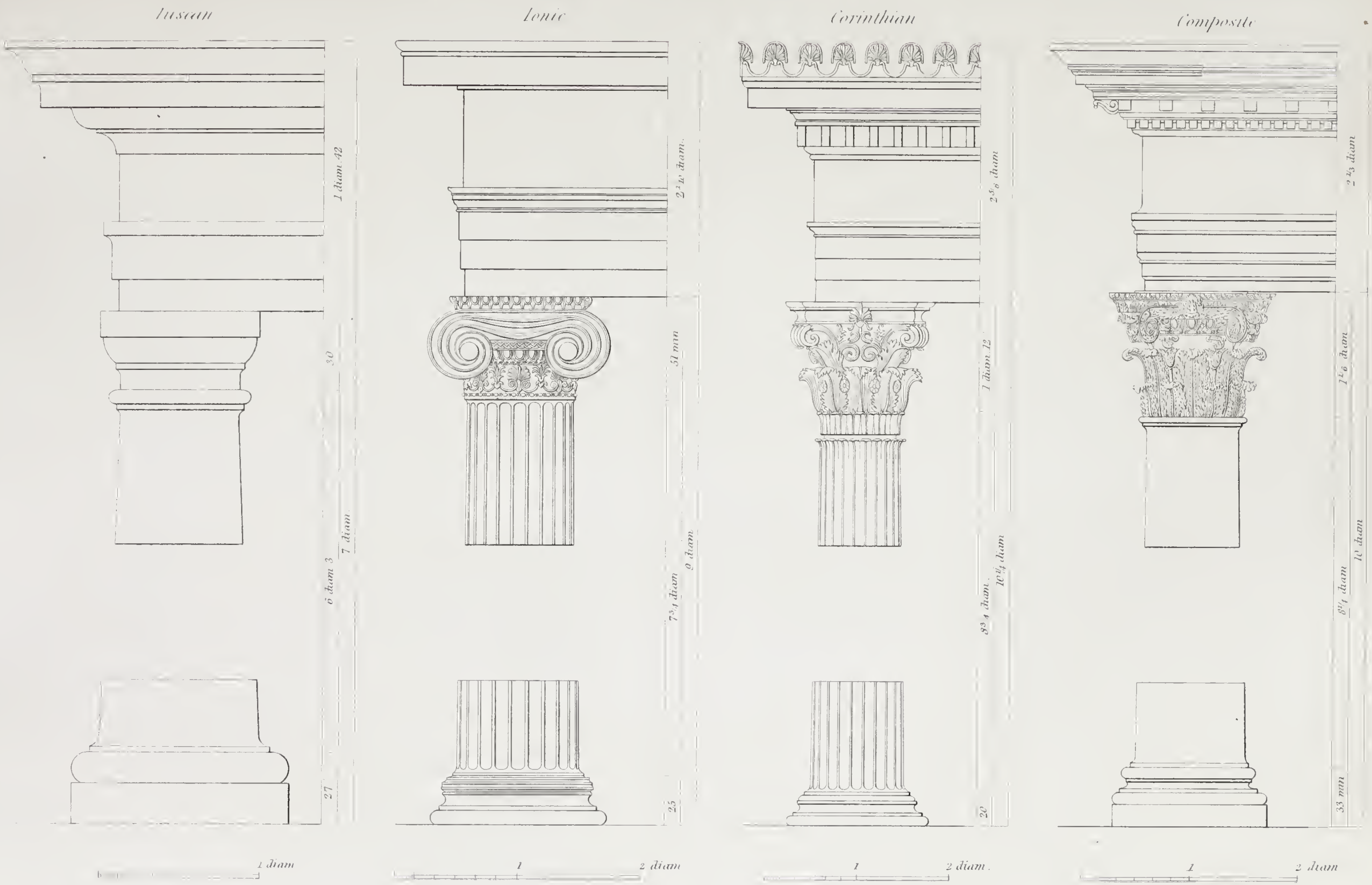

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Fig. 1.

Fig. 2.

Fig. 3

Fig. 4.

Fig. 5.

Fig. 6.

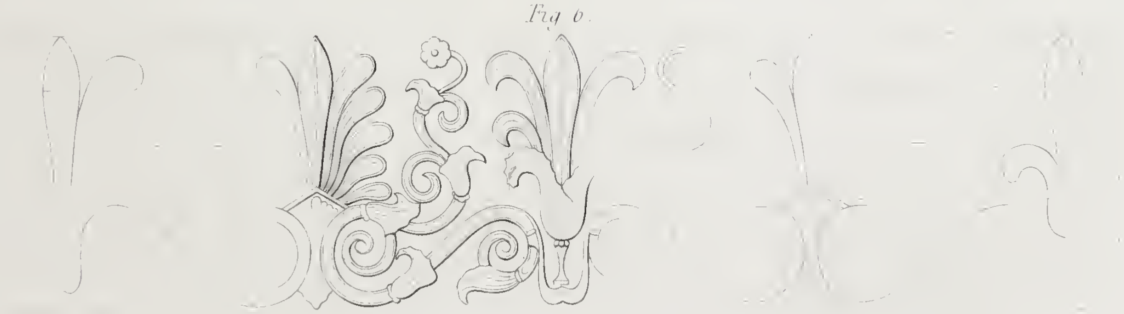

Fig. 7

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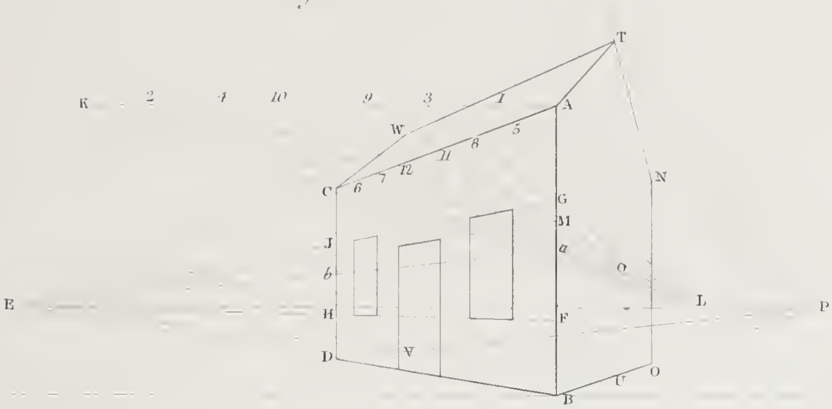
Fig. 2.



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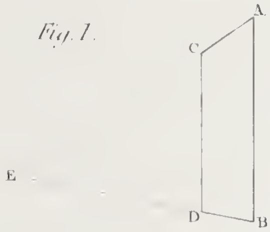

Fig. 4.

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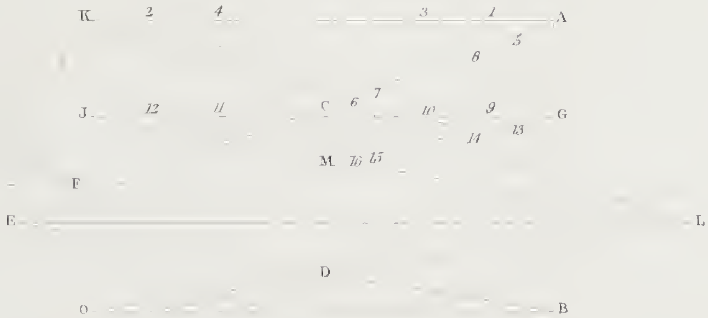

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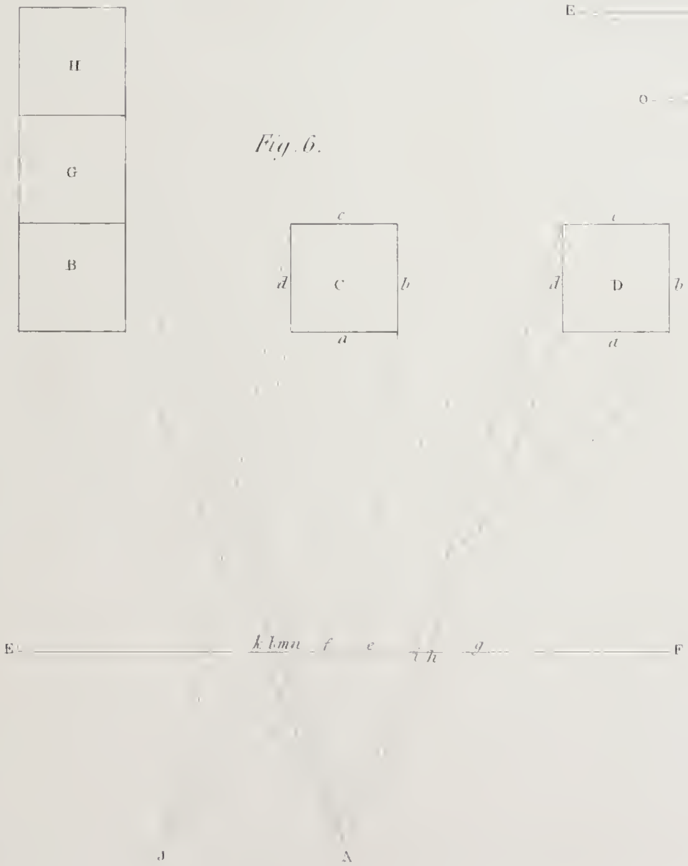

Fig. 5.

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Fig. 2. Prop. 1 & 2.

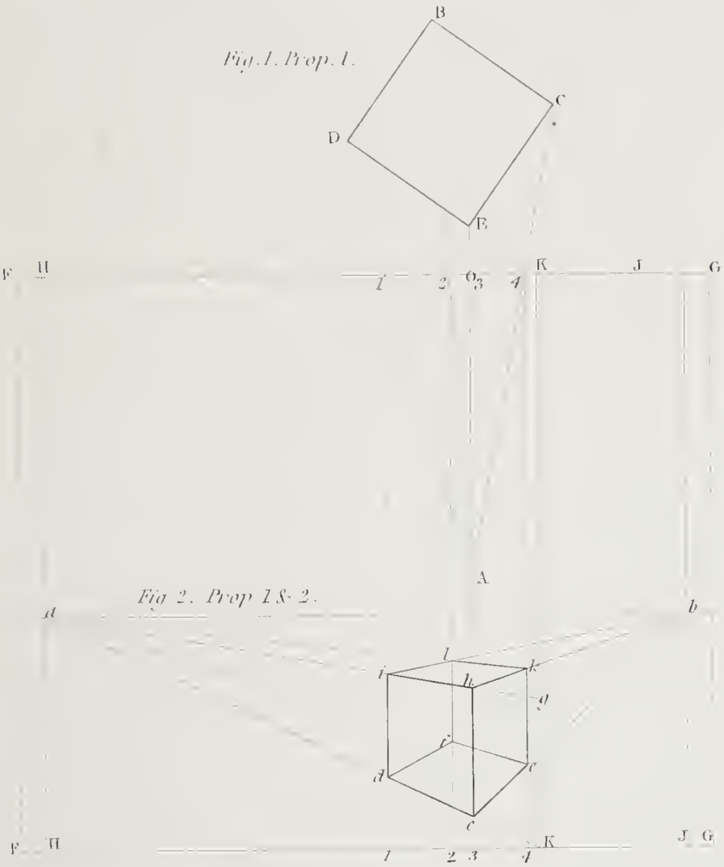
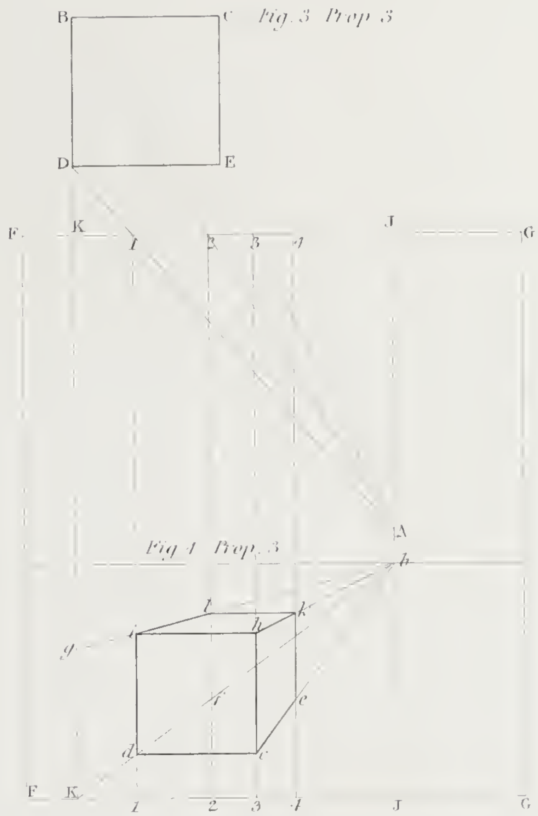


Fig. 3. Prop. 3.

Fig. 4. Prop. 3.



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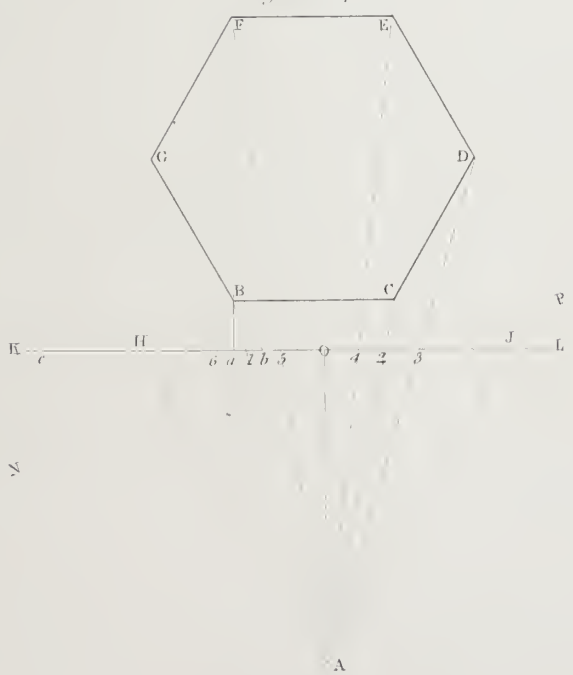

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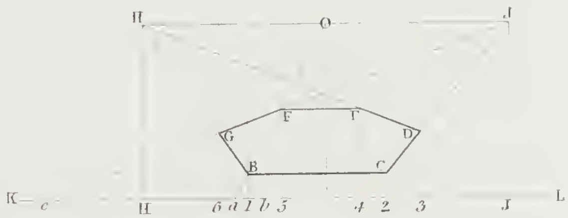

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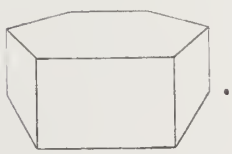

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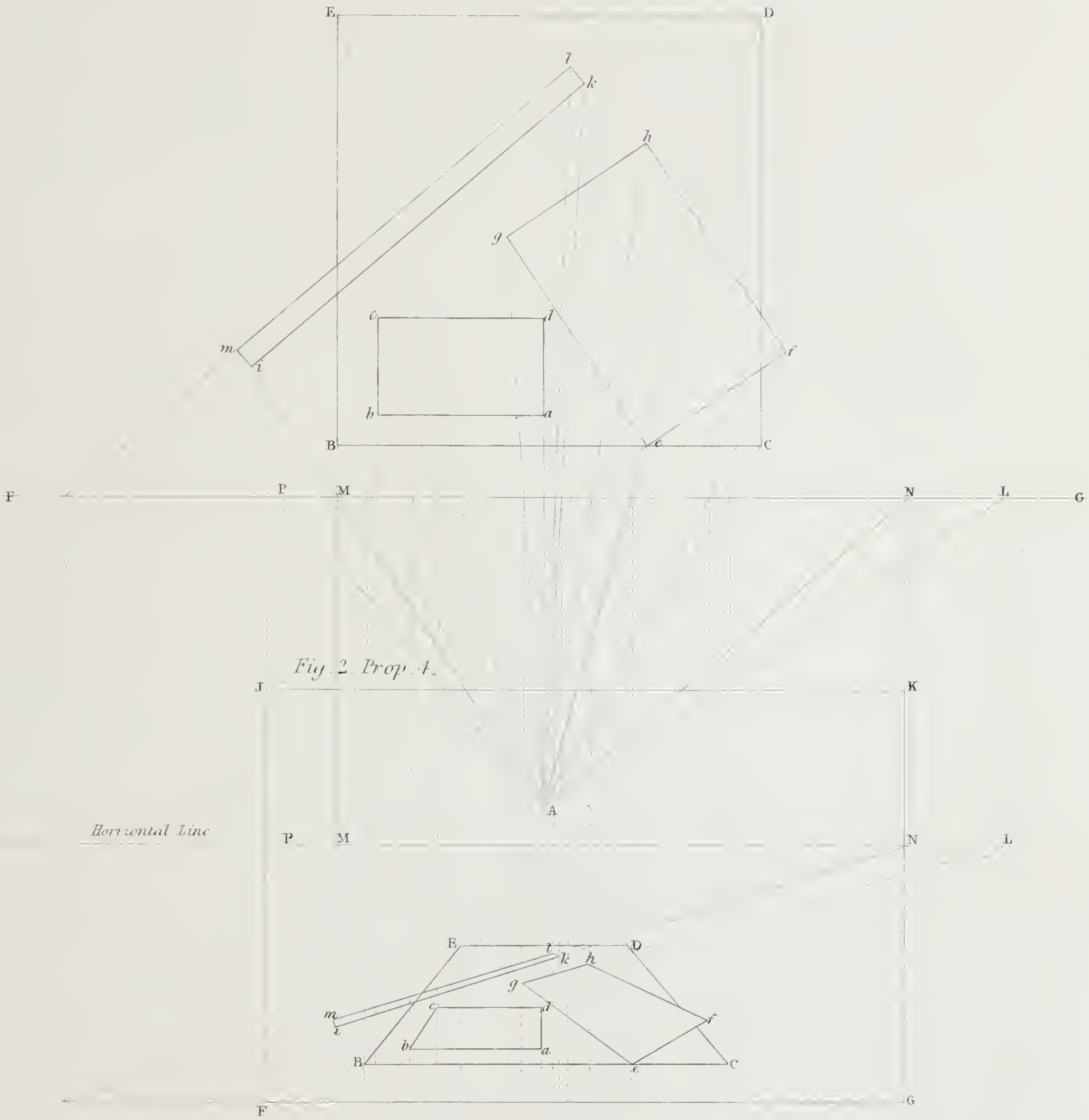

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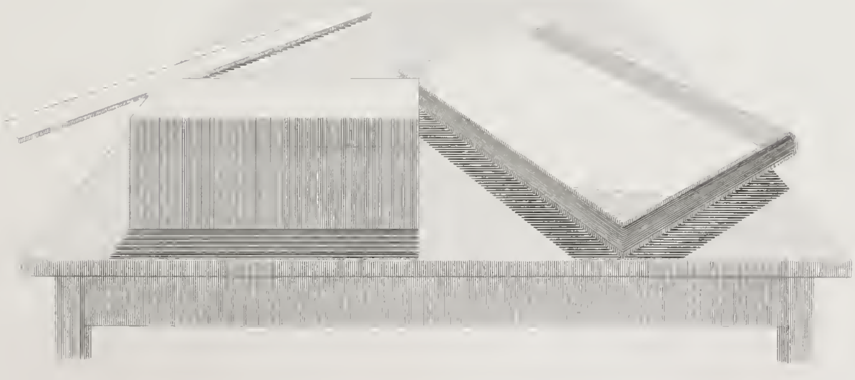

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Fig. 1. Prop. 6.

Fig. 2. Prop. 6.

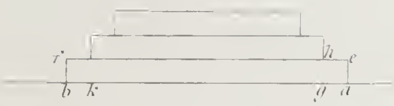


Fig. 3. Prop. 6.

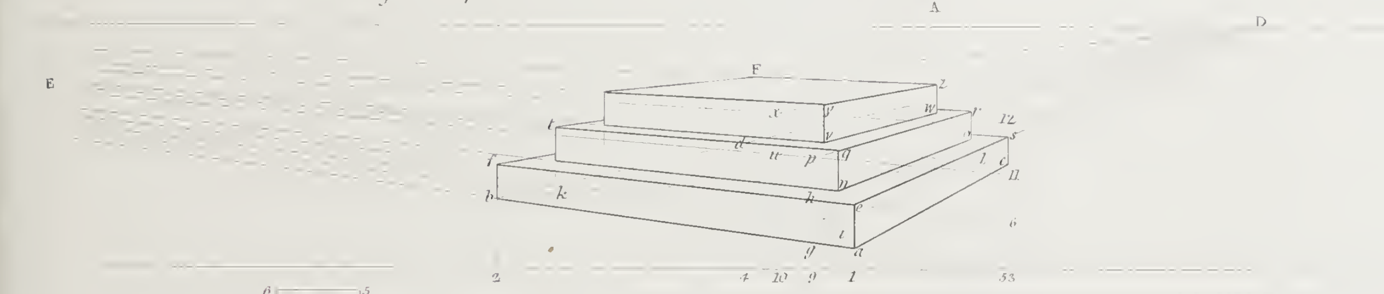
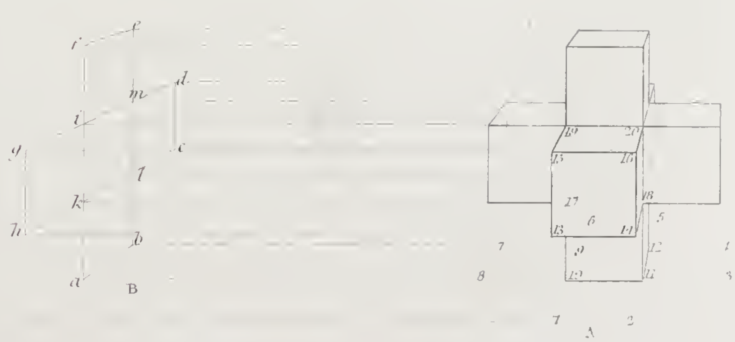


Fig. 4.

Fig. 5.

Fig. 6



G. Pyne inv.t et del.t

London John Weale 59 High Holborn 1847

Fig. 1. Prop. 7.

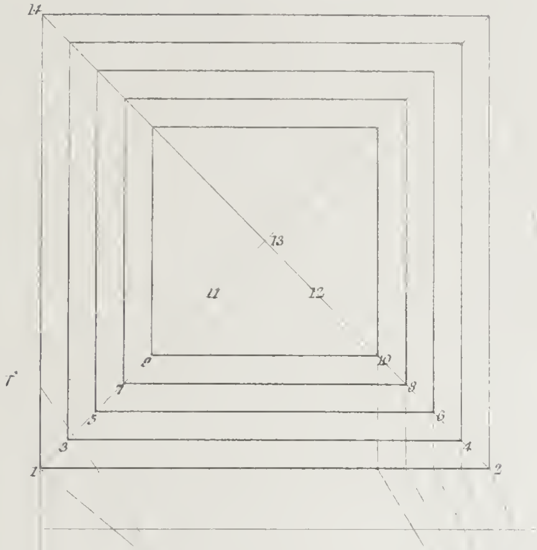


Fig. 2. Prop. 7.

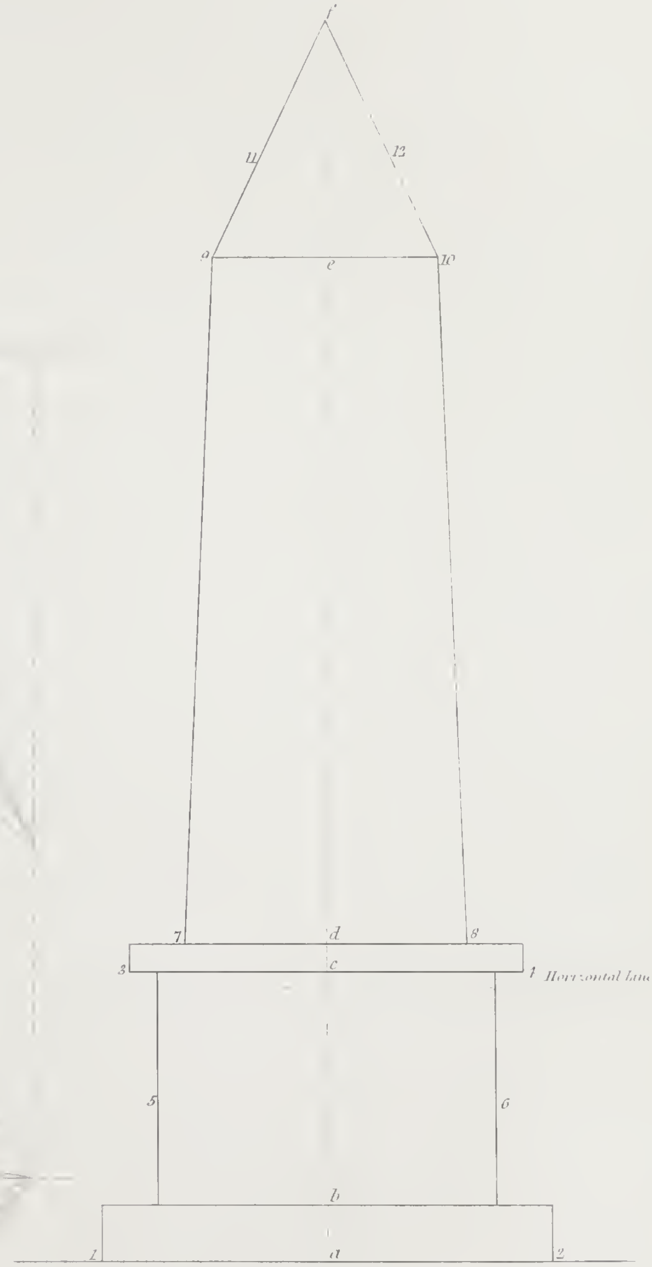
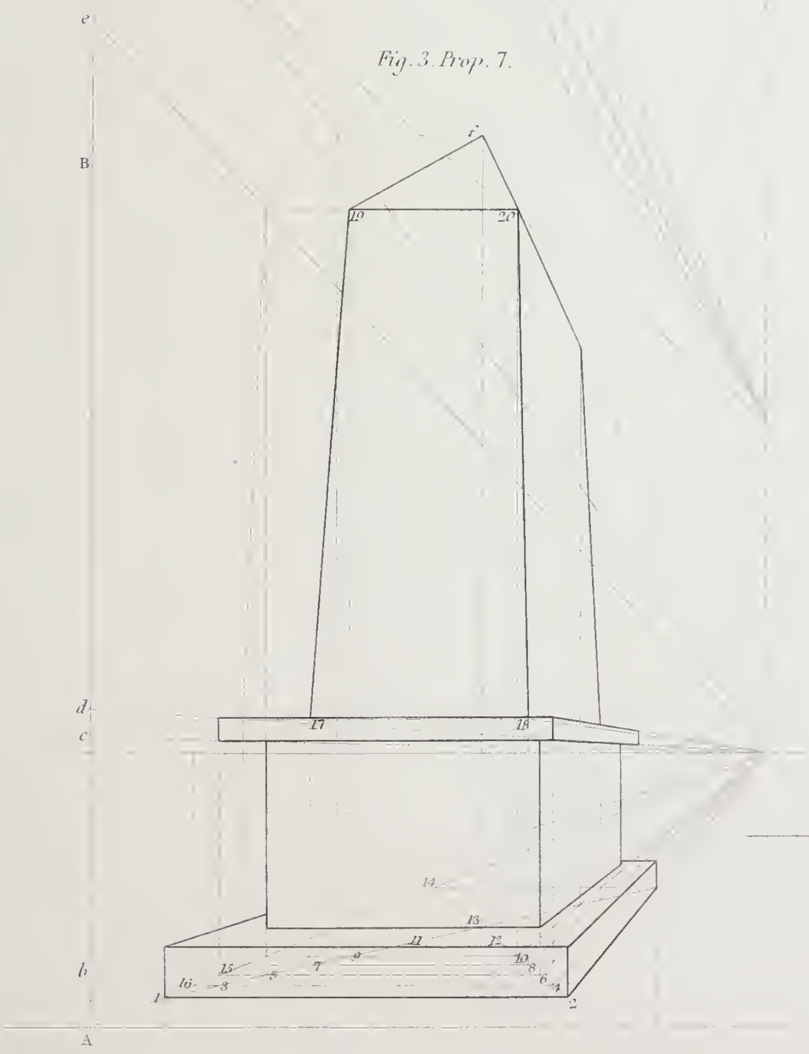


Fig. 3. Prop. 7.

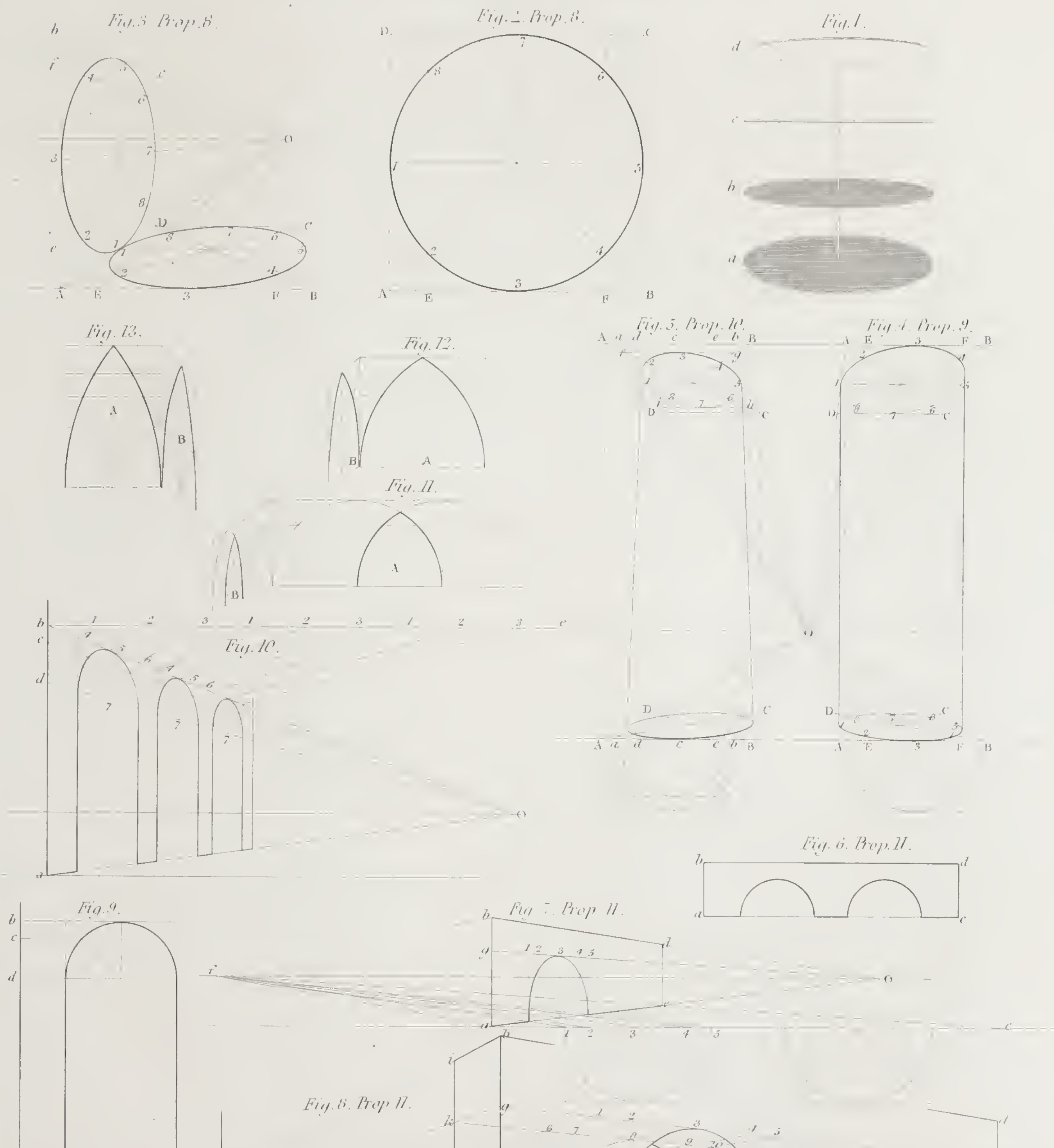


G. Pyne inv.t et del.t

J. W. Lowry f.

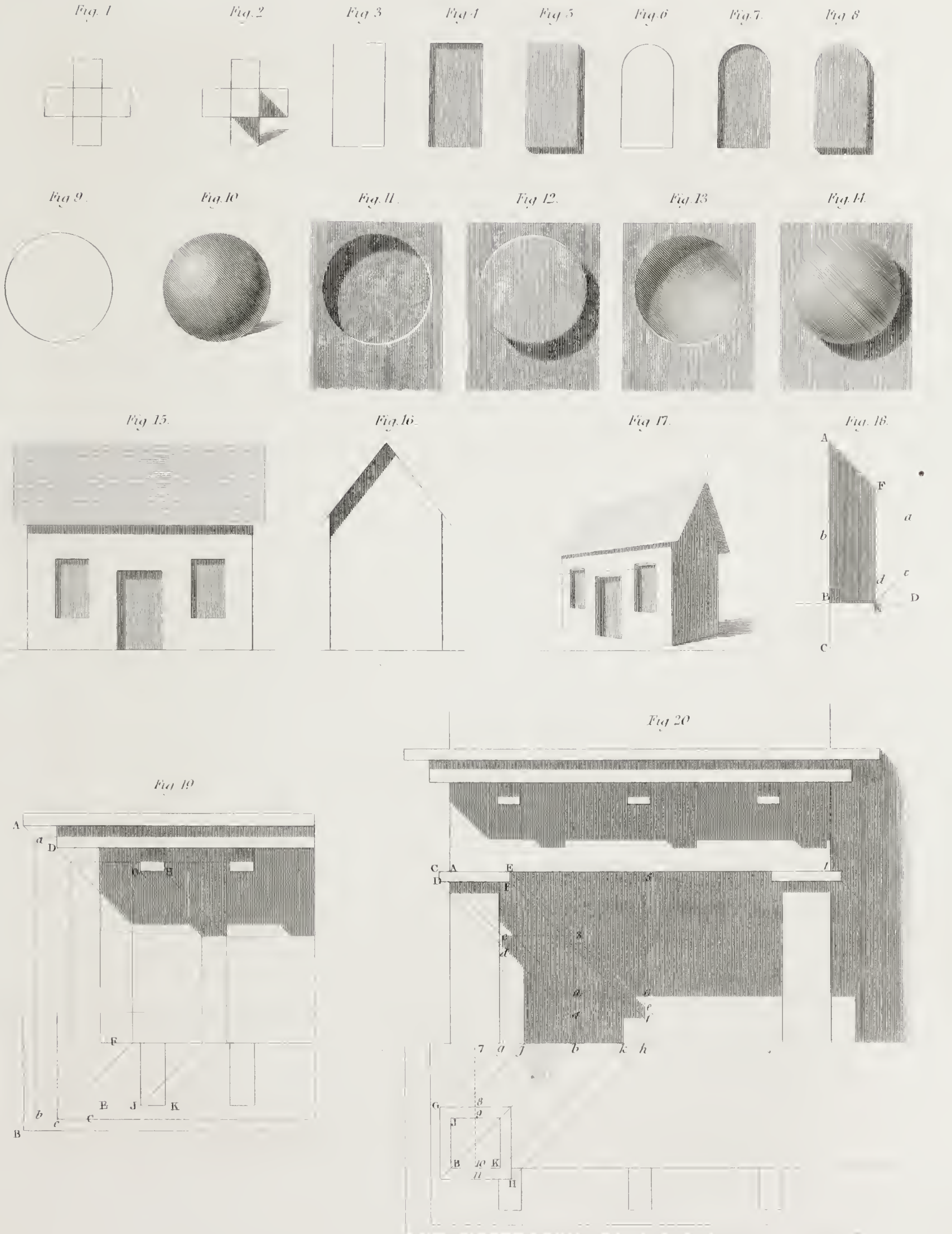
London John Weale 59 High Holborn 1847.

PRACTICAL RULES ON DRAWING PL. 13.



G. Pyne Inv.t et del.t

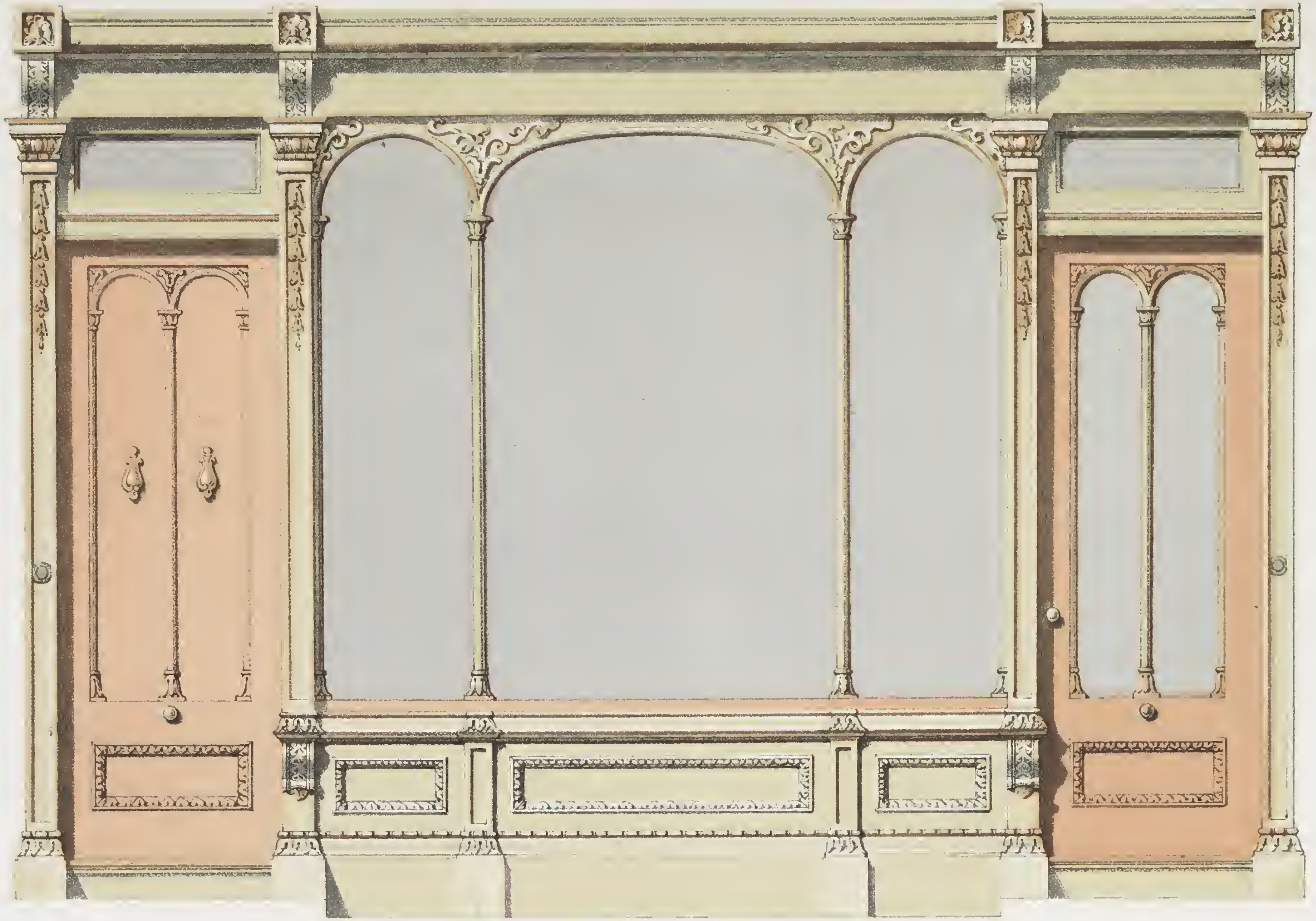
PRACTICAL RULES ON DRAWING PL. 11.



G. Pene inv. et del.

J. W. Lowry sc.

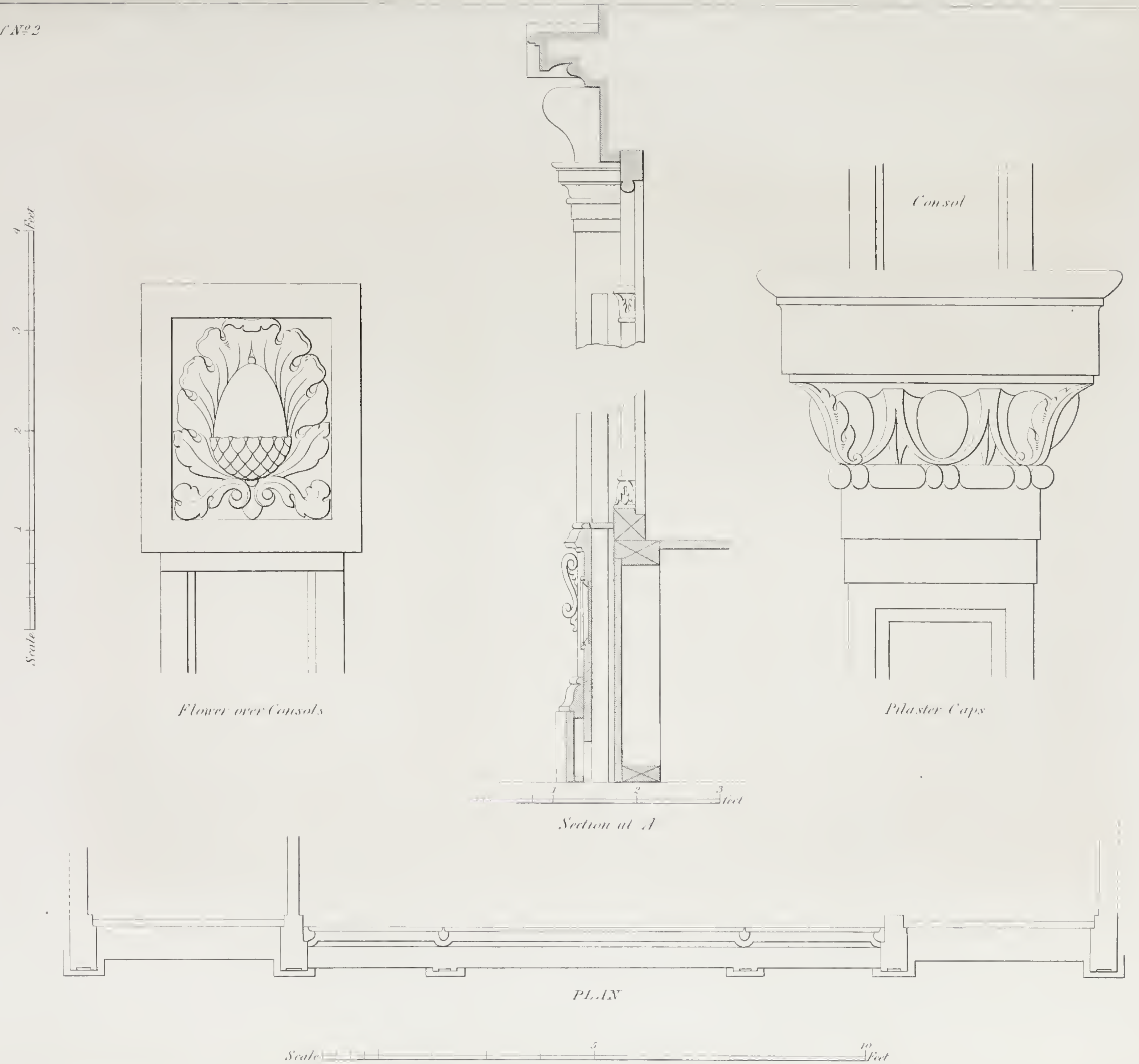
London, John Weale, 59 High Holborn, 1848.



SHOP FRONT A DYER FROM PARIS

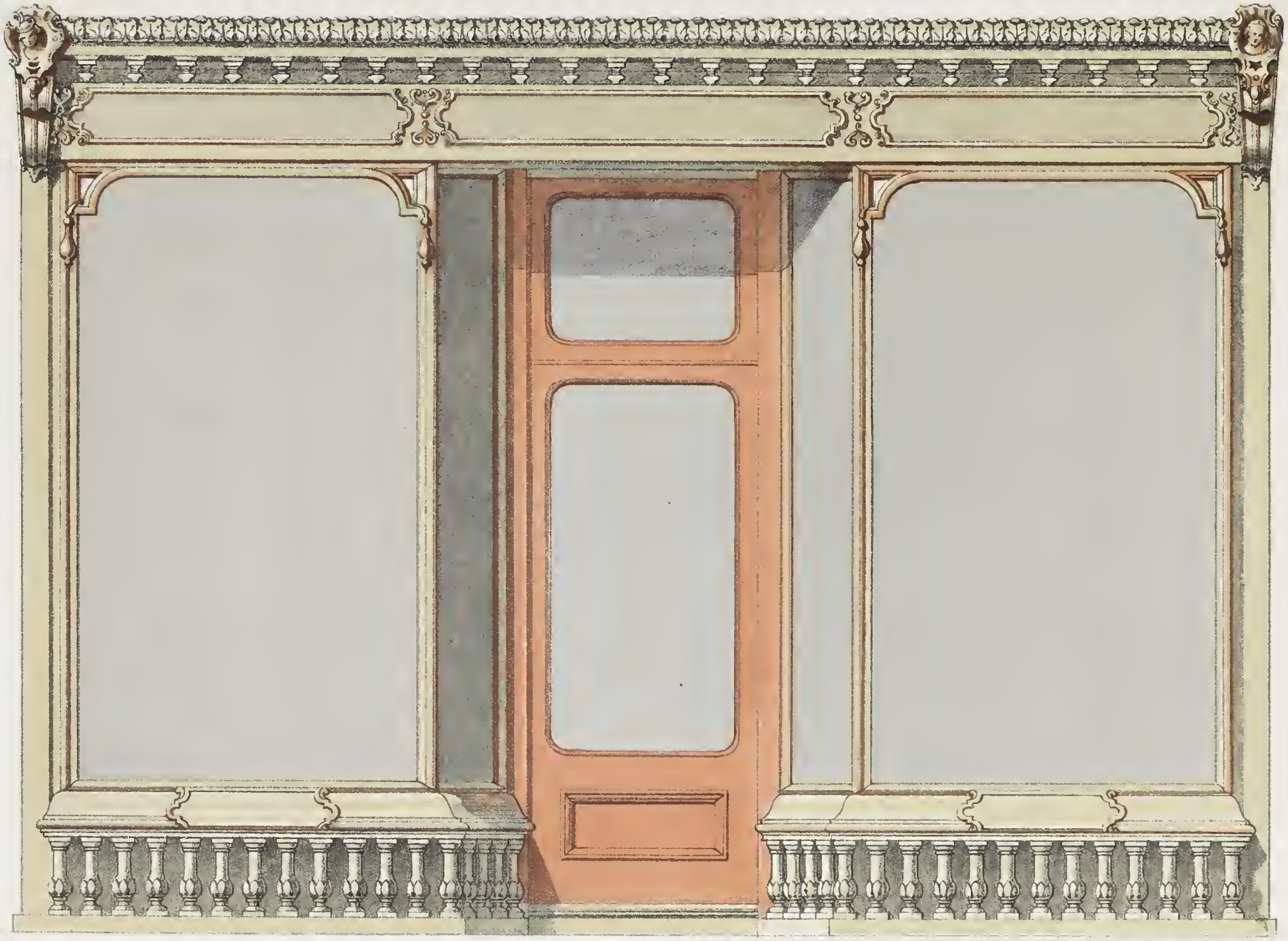
Elizabeth Street, Chester Square

Details of No. 2



John Weale, July 1 1847

John Weale, July 1 1847



UMBRELLA & CANE SHOP FRONT

Regent Street

Scale of 10 Feet

E. Gifford

Bedford Lithr. London

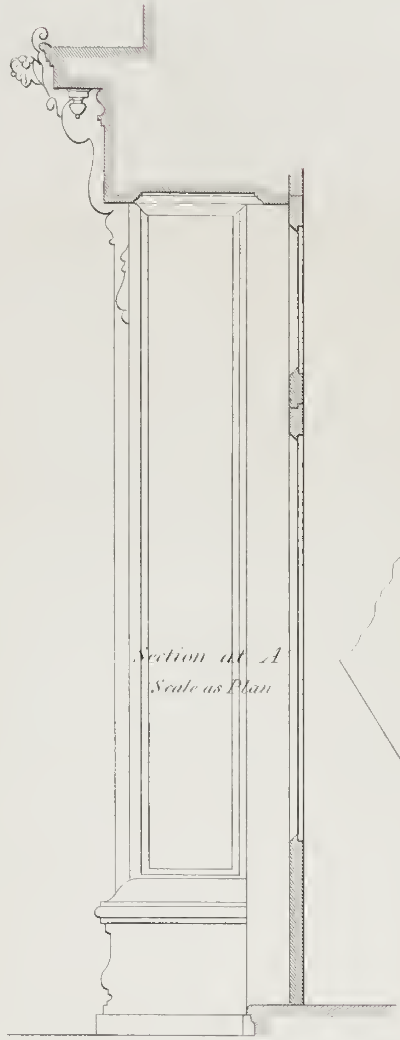
John Weale 59 High Holborn

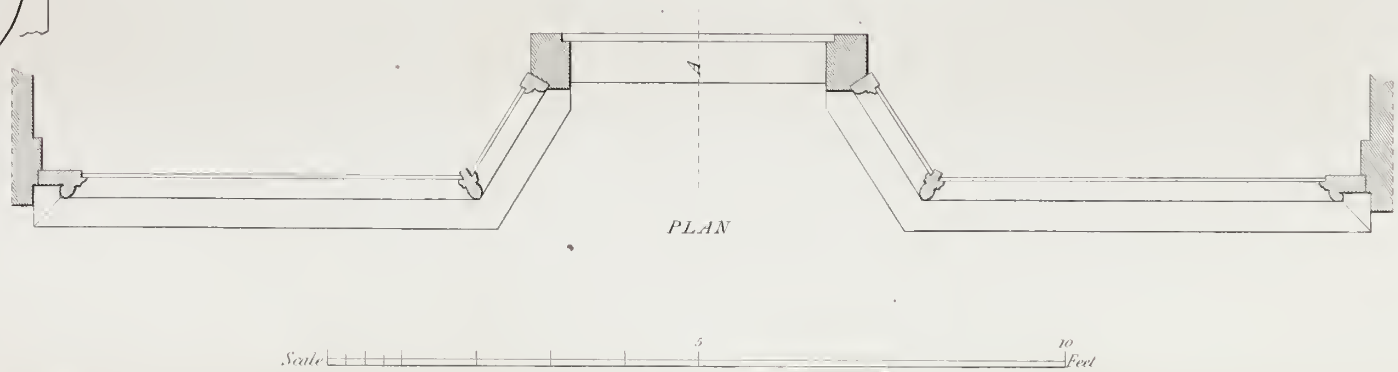
Printed by Standidge & Co.

E. Gifford del

John Weale July 1 1847

Details No. 3

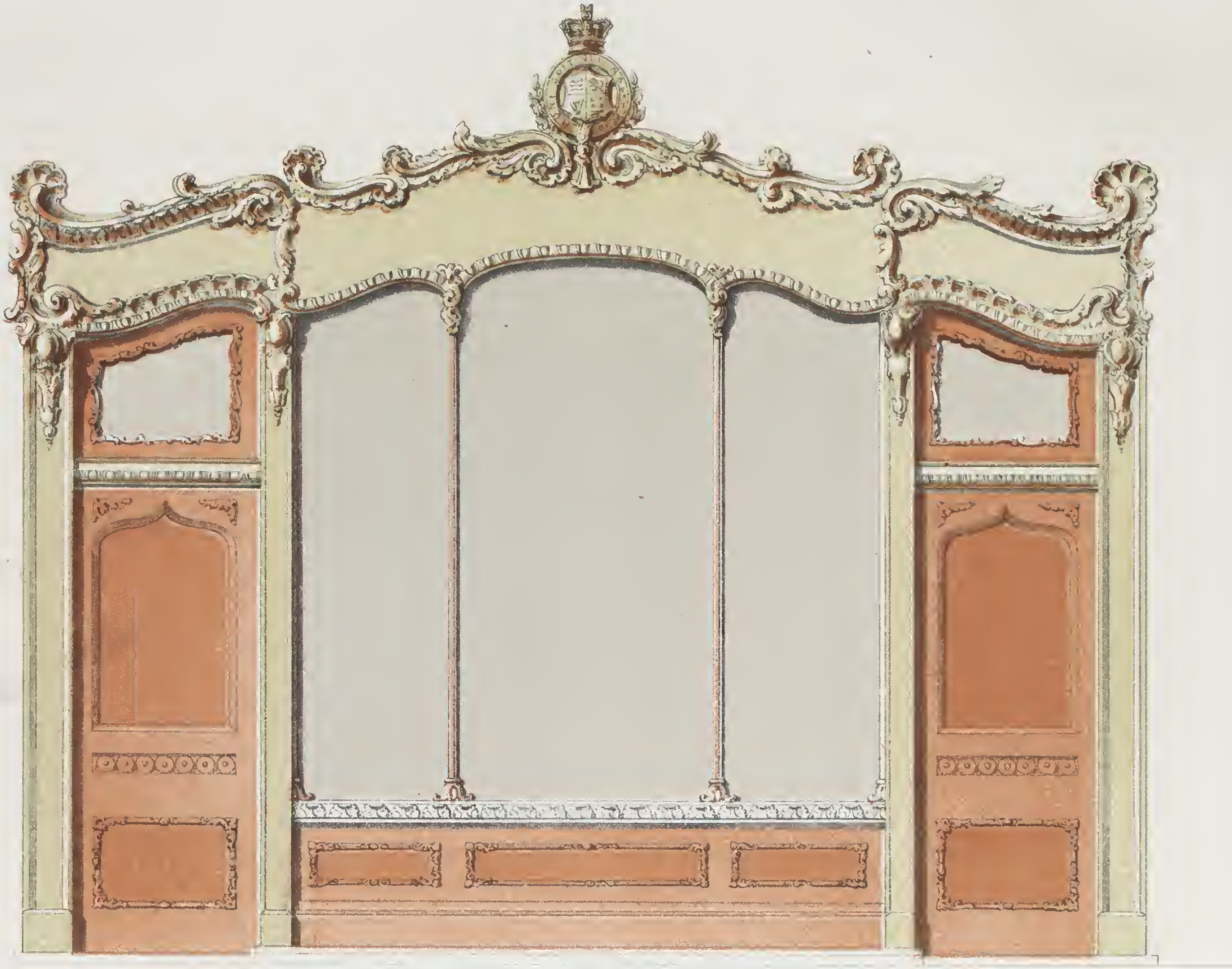




E. Gifford del.

John Weale July 1 1847.

W. A. Beever sc.



LADIES SHOE MAKERS SHOP FRONT

Mount Street, Grosvenor Square

Scale of 5 10 15 20 Feet

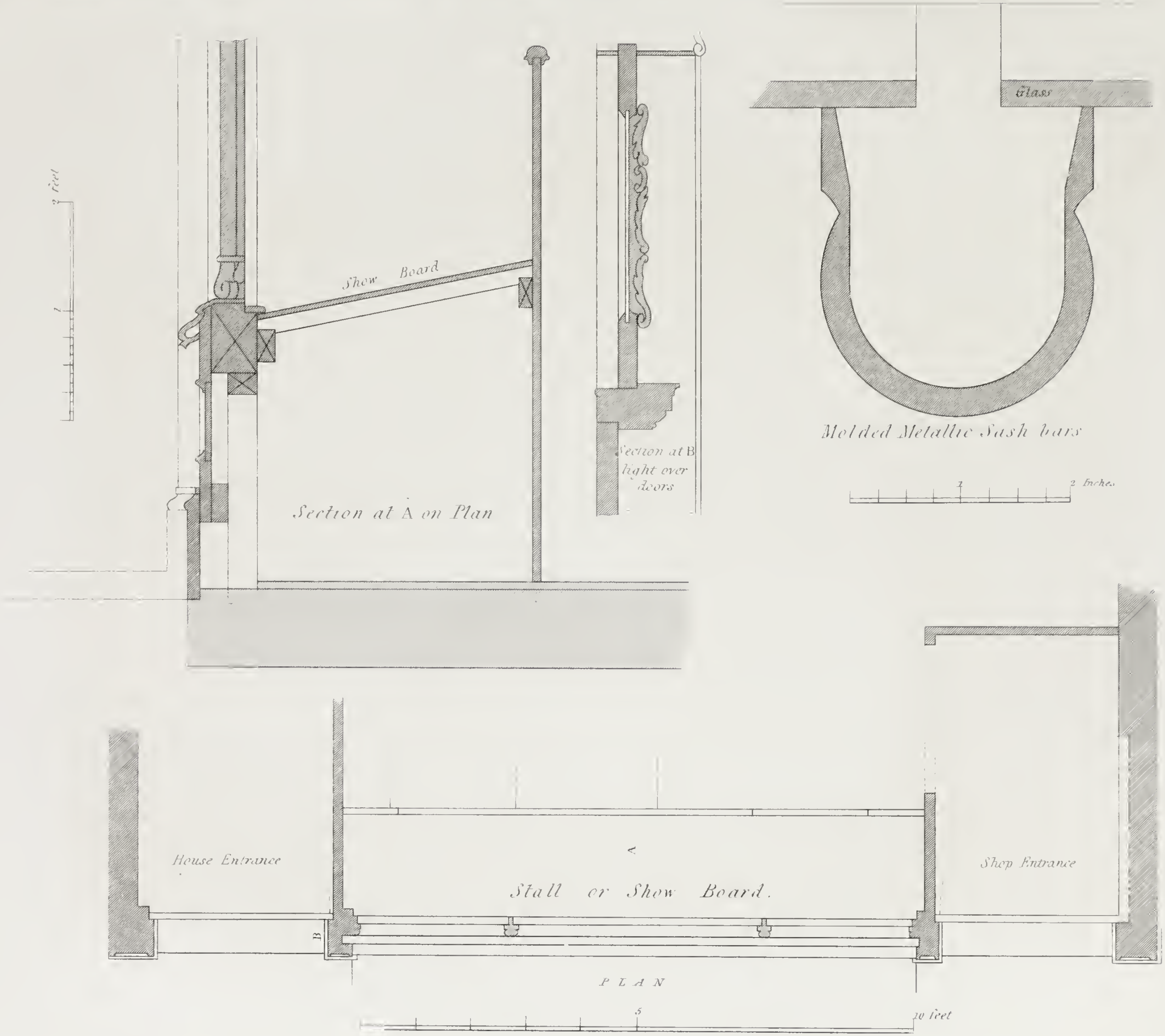
F. Bedford Delt.

F. Bedford Lithr. London

John Weale 59 High Holborn

Printed by Standidge & Co.

SHOP FRONT IN MOUNT STREET.

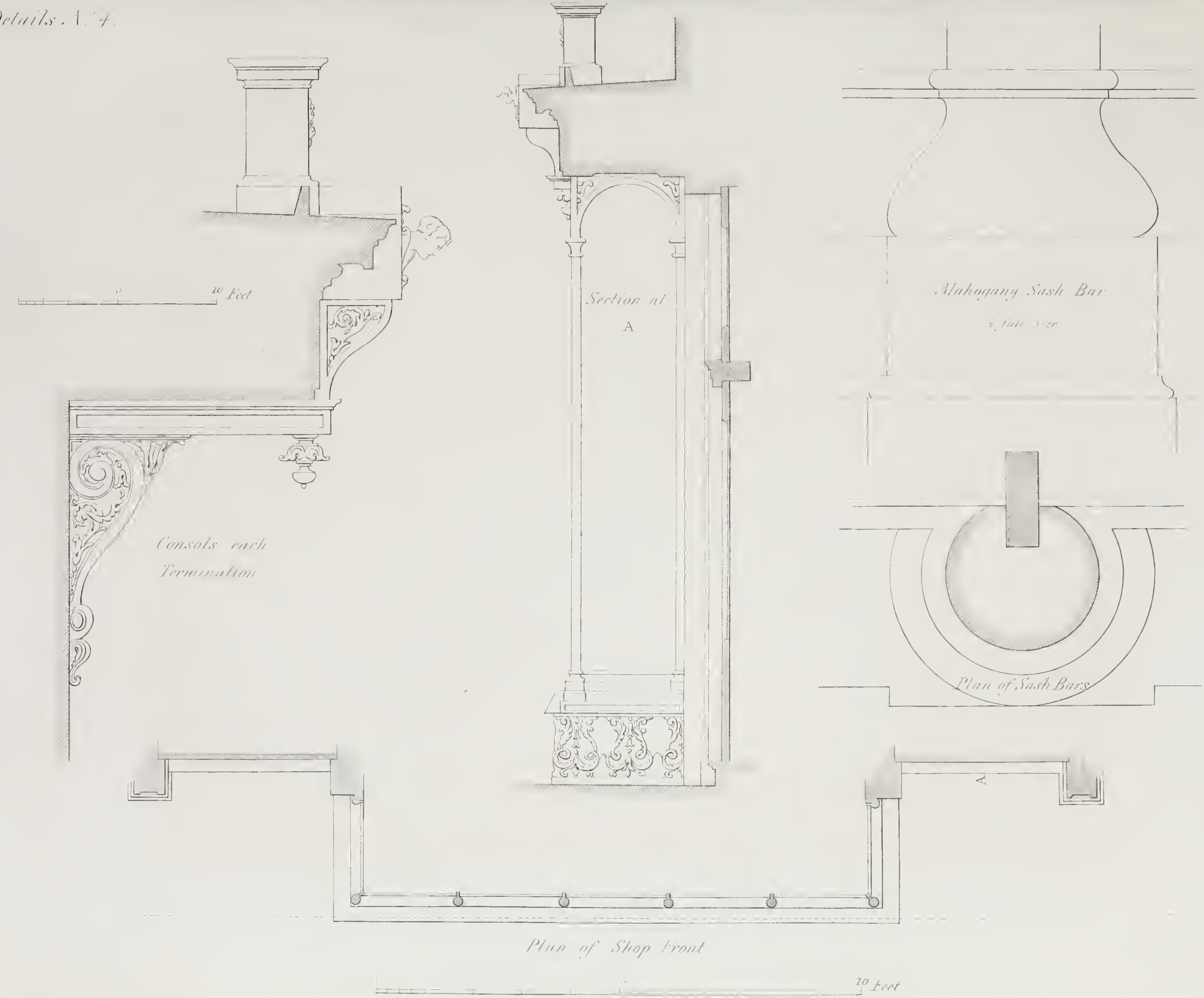


R. osenberg sc

John Weale June 1, 1847

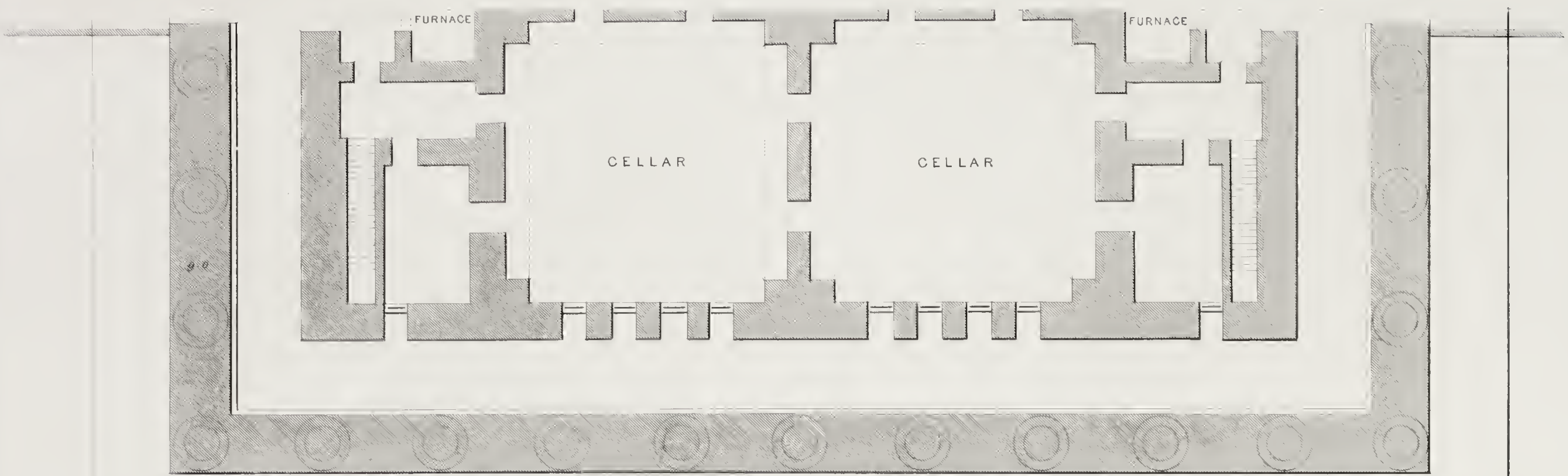
TAILOR & DRAPER'S SHOP FRONT

Details. N.° 4.


10 Feet
Consols each Termination
Section at A
Mahogany Sash Bar
½ full size
Plan of Sash Bars
A
Plan of Shop Front
10 Feet

Practical B

HALF PLAN OF FIRST STORY — MAIN BUILDING.



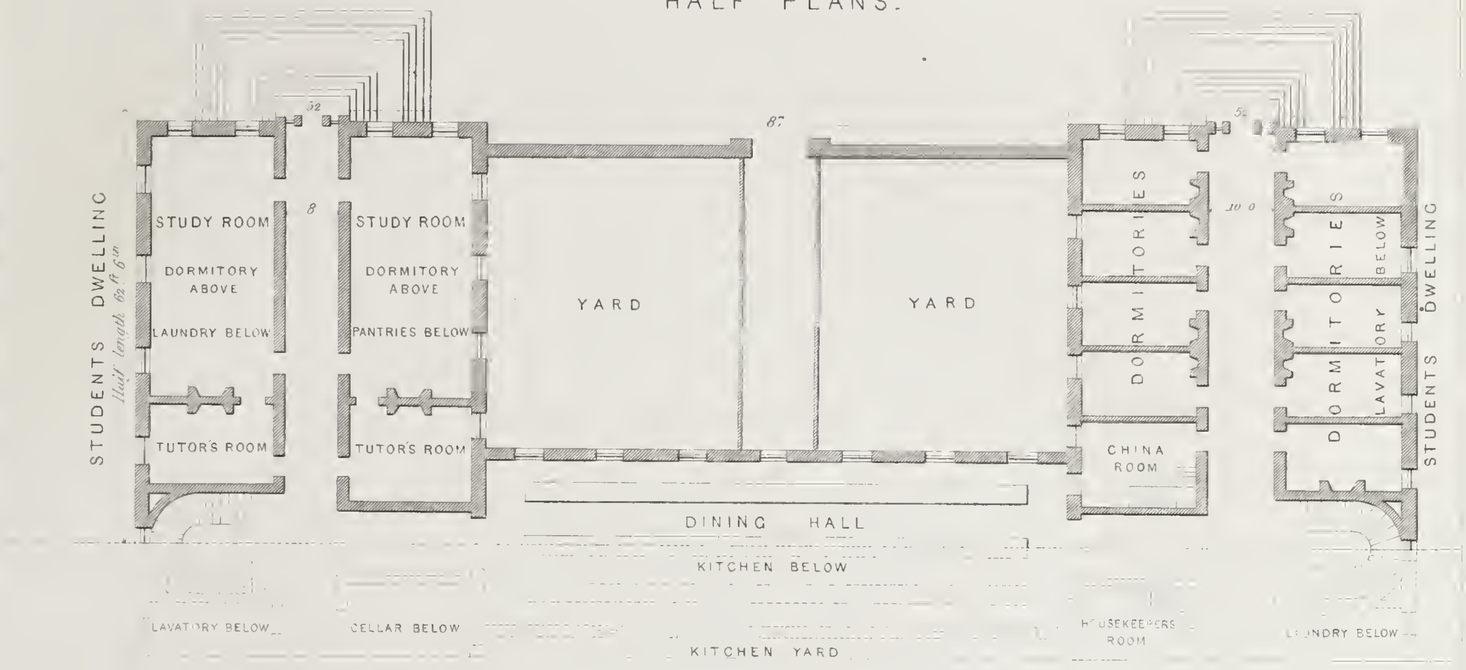
HALF PLAN OF FOUNDATIONS — MAIN BUILDING.

Scale 28 feet to an inch 10 20 30 40 50 60 70 80 90 100

GIRARD COLLEGE.

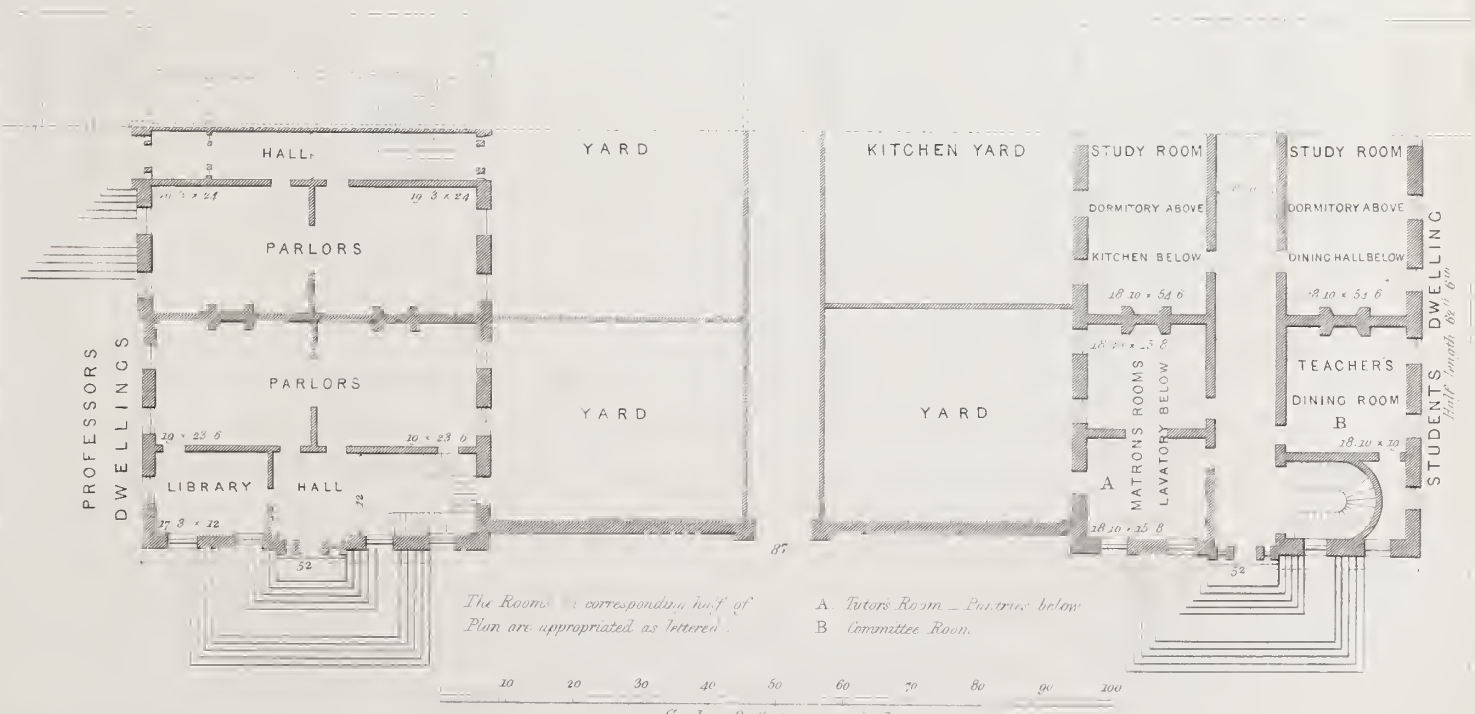
London. Published ... July 1st 1847

HALF PLANS.



WESTERN OUT BUILDINGS

EASTERN OUT BUILDINGS.



The Rooms in corresponding half of Plan are appropriated as lettered.

A. *Tutor's Room — Pantries below*
B. *Committee Room.*

Scale 28 feet to an inch.

GIRARD COLLEGE.

... High Holborn July 1st 1847

Practical B

GIRARD COLLEGE.

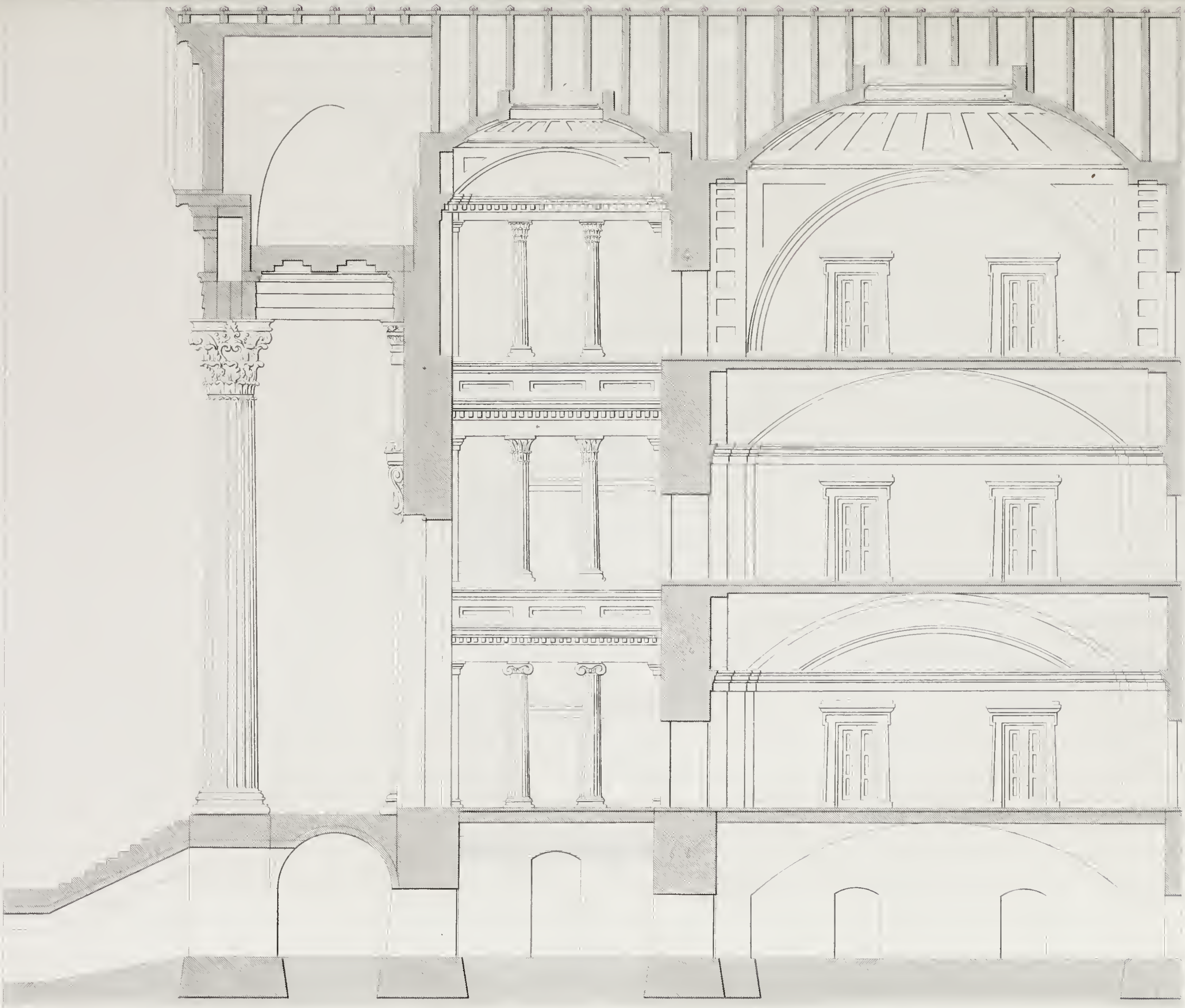
MAIN BUILDING

MAIN BUILDING_HALF OF SIDE ELEVATION.

GIRARD COLLEGE.

Practical B.

LONGITUDINAL SECTION THROUGH HALF OF THE MAIN BUILDING.



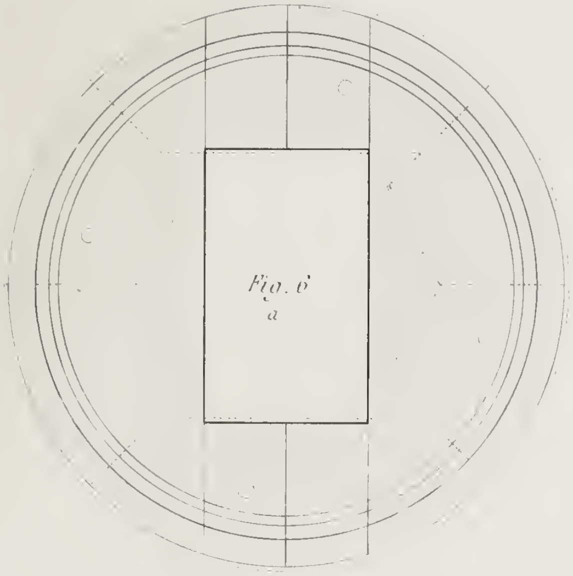
T. U. Walter Arch.

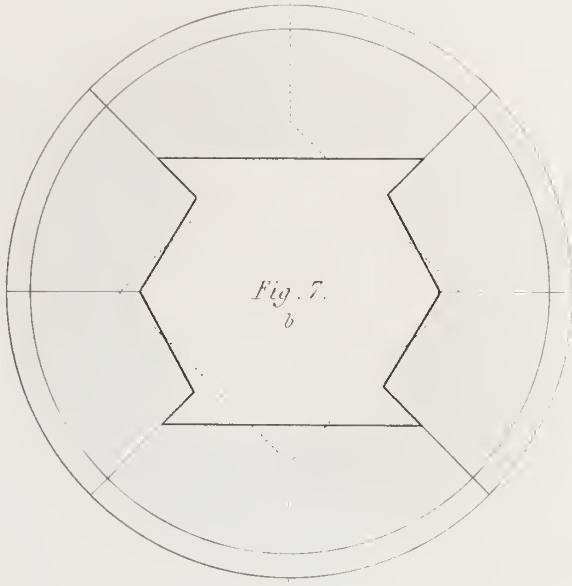
Scale 5 10 20 30 40 50 XIV Feet to an inch

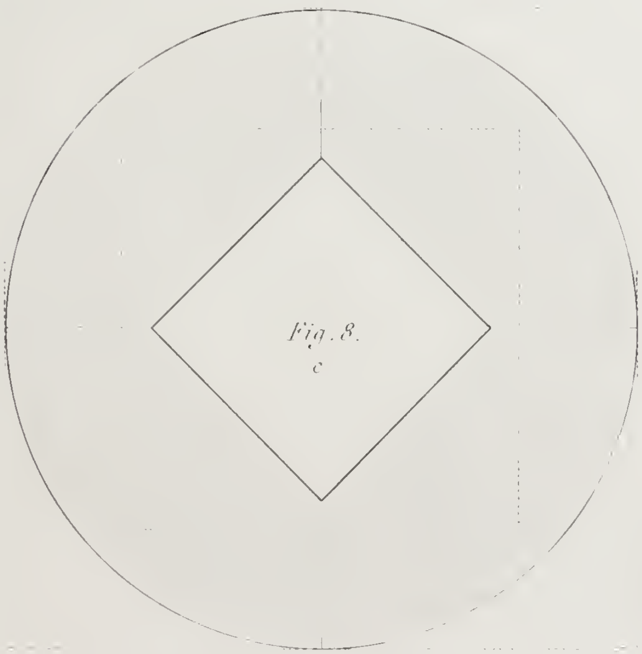
GIRARD COLLEGE.

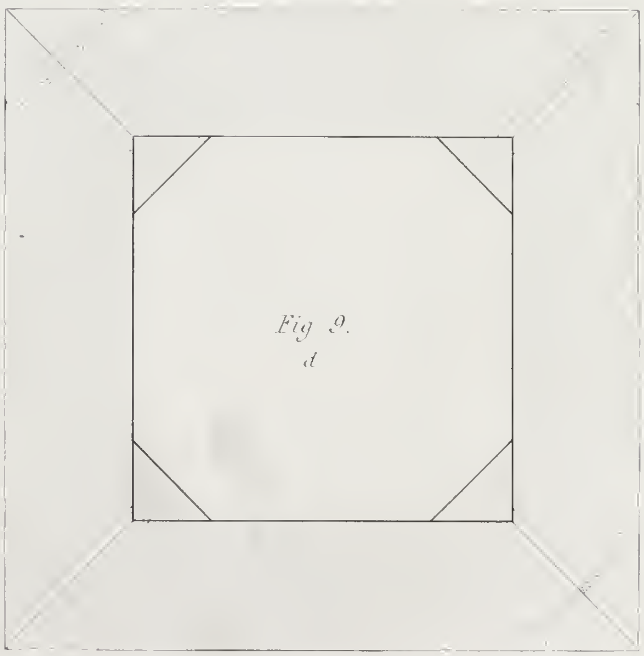
KINGS COLLEGE.

Details of the construction of one of the Wooden Columns in the New Hall









Figs. 6, 7, 8 & 9. Shew respectively the plans of the different thicknesses a, b, c, d, (Fig 1) of which the base is composed.

S. Smirke, del.

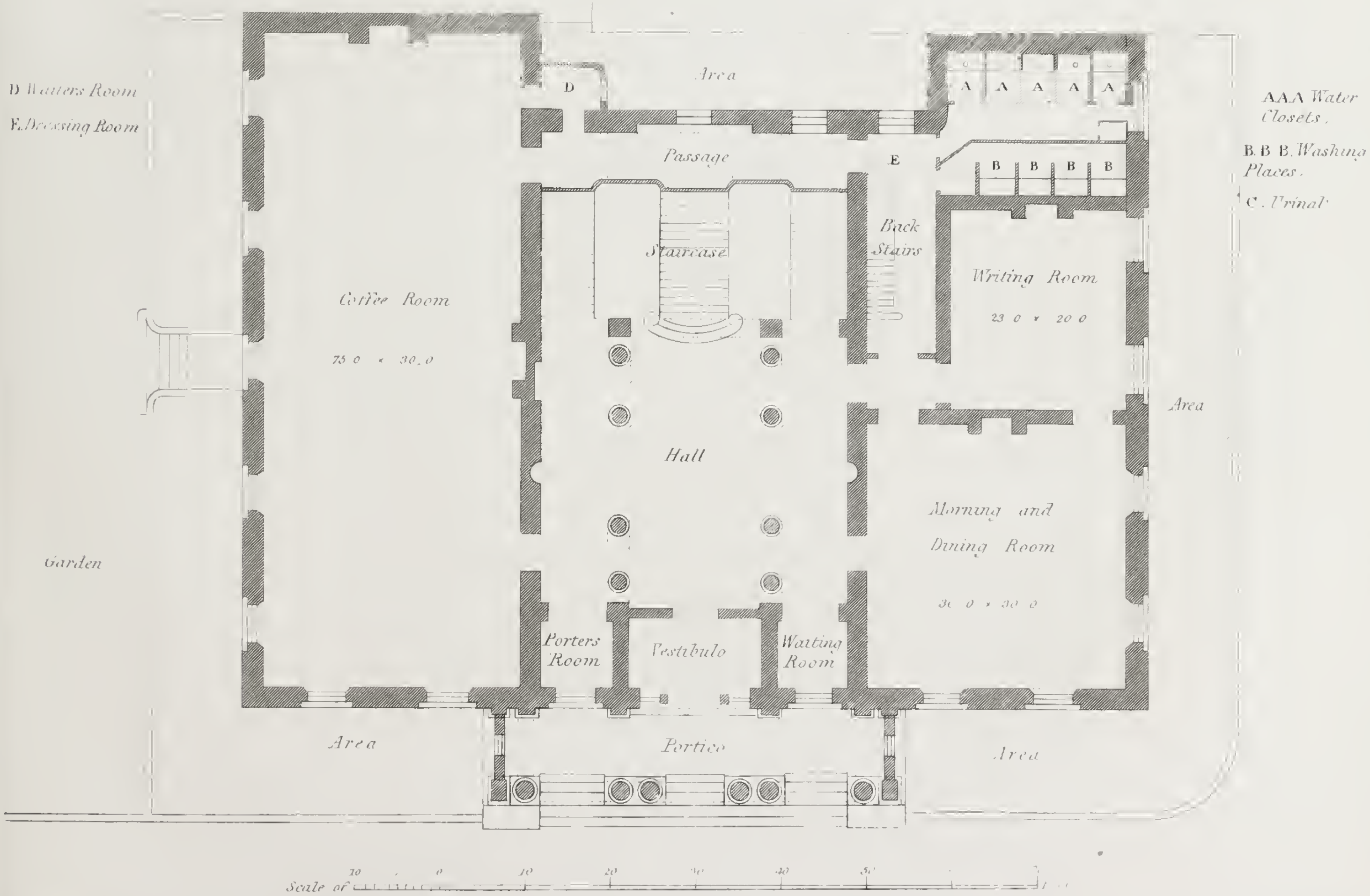
Ryan sc.

John Weale May 1831

ATHENÆUM CLUB HOUSE.

Elevation of the Principal Front.

Plan of the Ground Floor



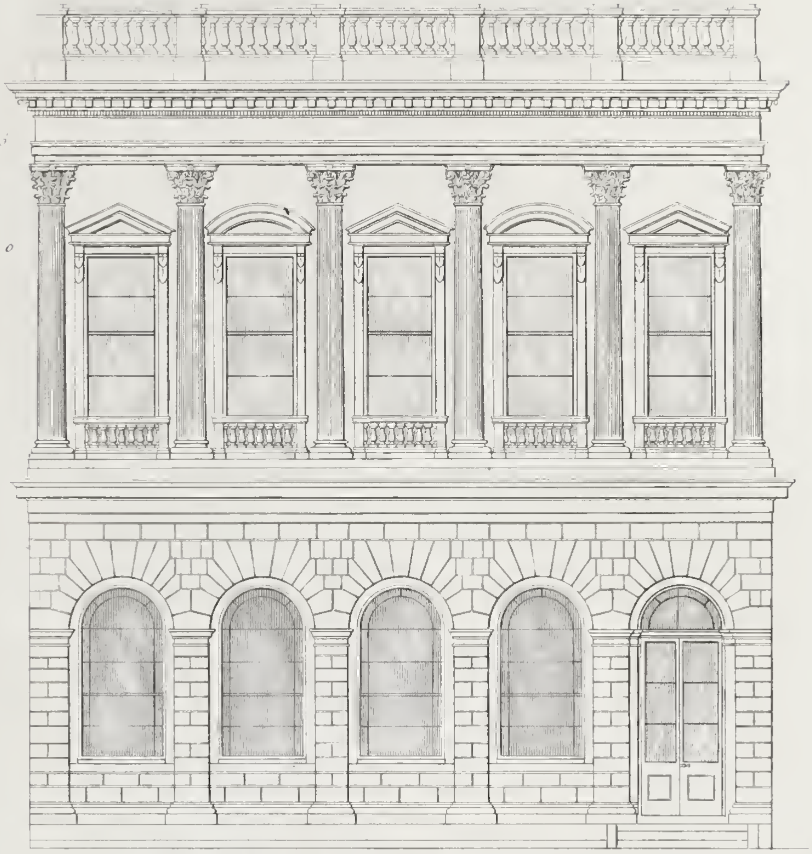
D. Burton Arch^t

Drawn by E.W. Trendall

John Weale Mon? 1847

ARTHUR CLUB HOUSE.

Elevation of the Principal Front.

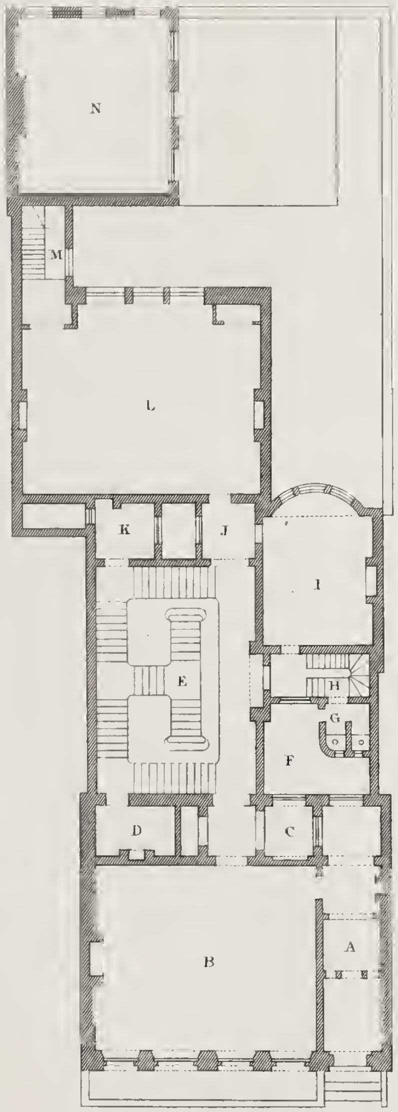


10 5 0 10

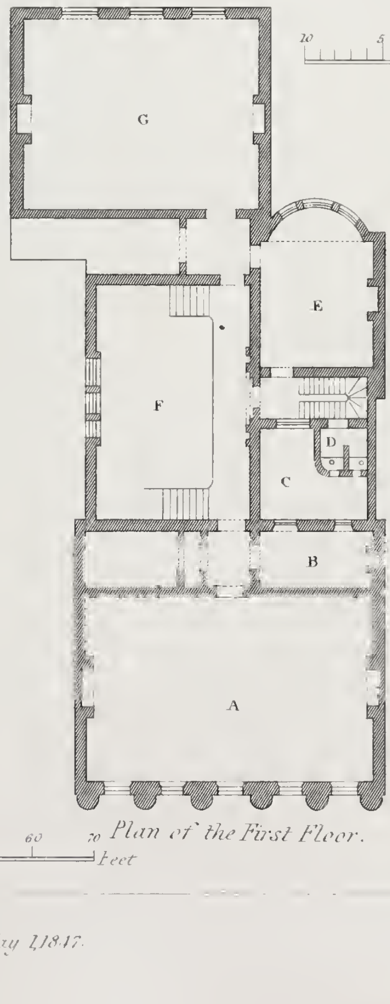
Elevation

Reference to the Ground Plan.

A. Entrance Hall.
B. Coffee Room. 35, 6 × 29, 3
C. Lobbey.
D. Bar.
E. Principal Staircase. 36, 0 × 25, 6
F. Area.
G. Water Closets.
H. Back Stairs
I. Dining Room 25, 0 × 18, 3
J. Lobbey
K. Stewards Room.
L. Dining Room. 39, 0 × 29, 0
M. Stairs from Kitchen.
N. Upper part of Kitchen.



Plan of the Ground Floor.



Reference to Plan of First Floor.

A. Library _ 47, 6 × 29, 6
B. Secretarys Room.
C. Open Area.
D. Water Closets
E. Billiard Room.
F. Upper part of Staircase.
G. Drawing Room.

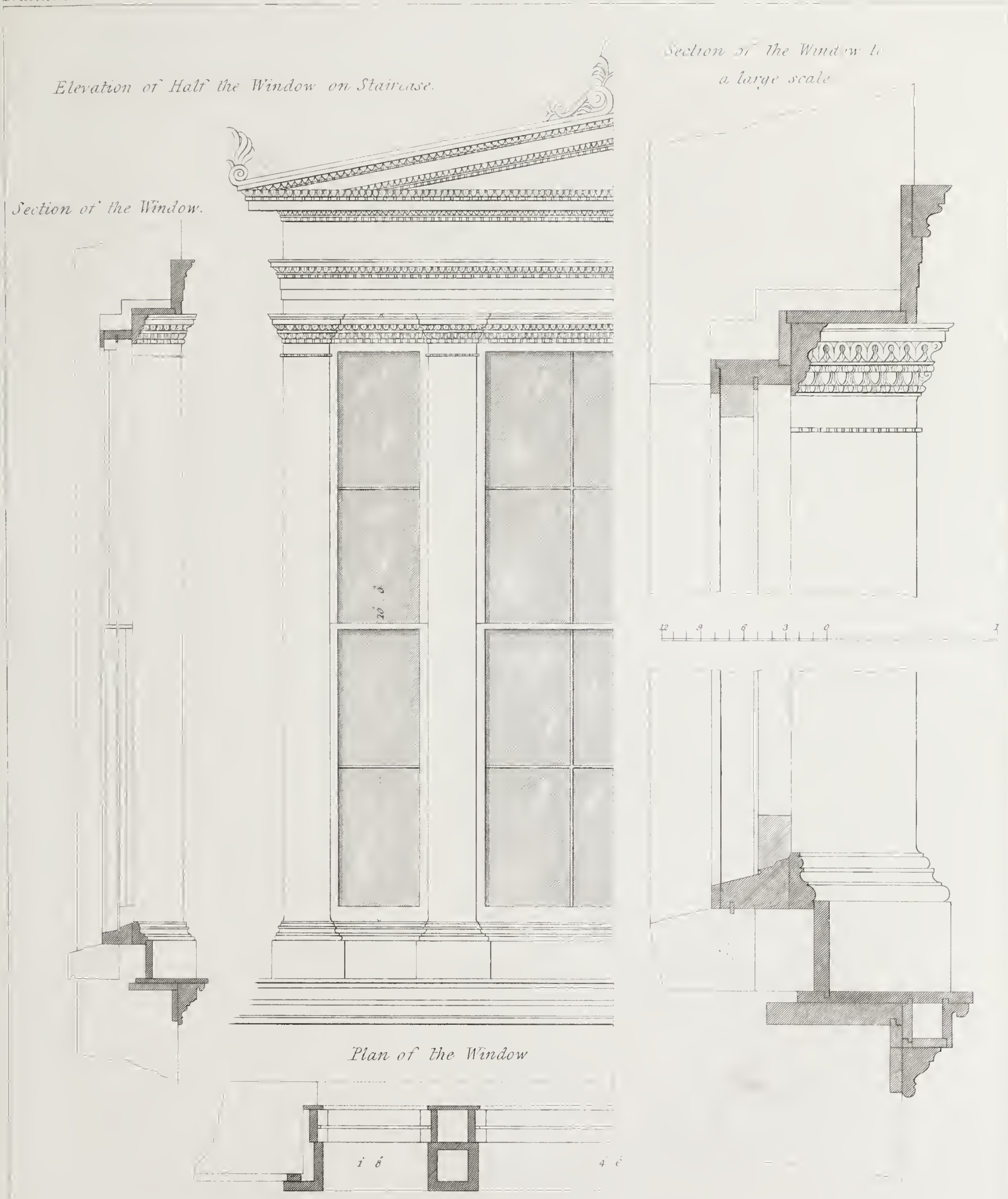
Plan

Scale of 10 5 0 10 20 30 40 50 60 70 Feet

Plan of the First Floor.

E. W. Trendall, del. C. Rosenberg, sc.

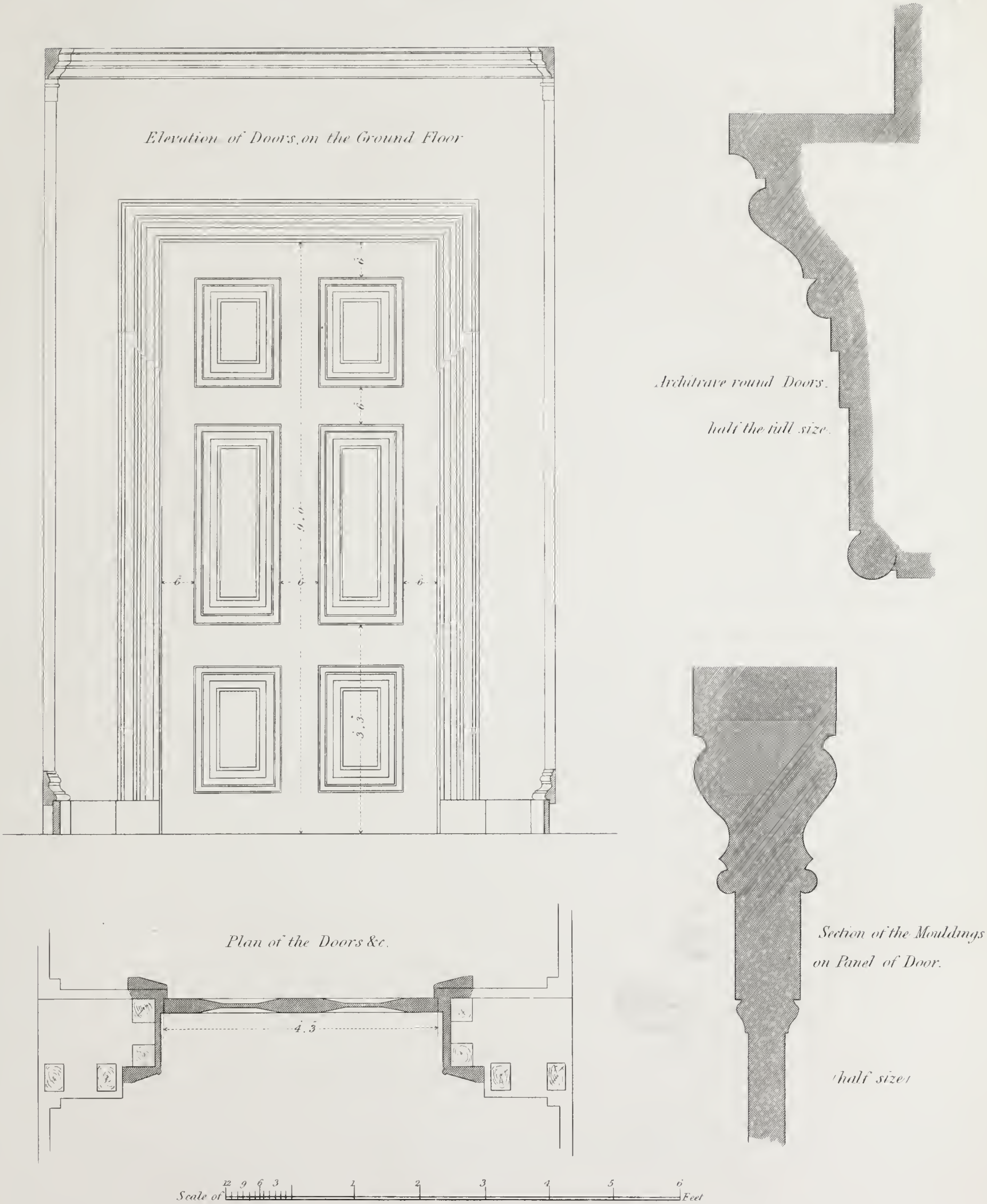
John Weale, May 1, 1847.



Drawn by E W Trendall

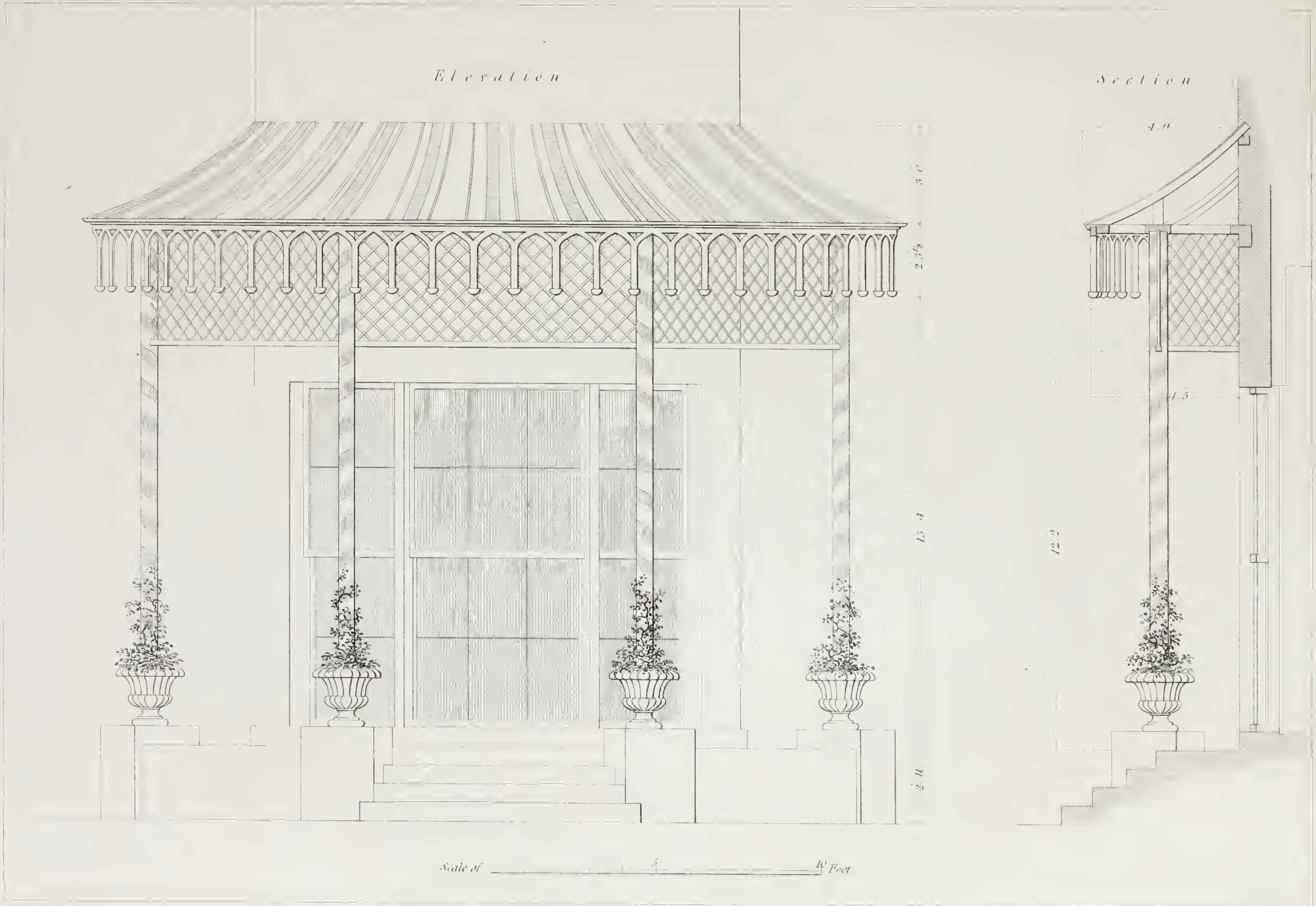
John Weale, June 1 1847

Arthur's Club House



T. Hopper, Archt.

John Weale June 1.1847.

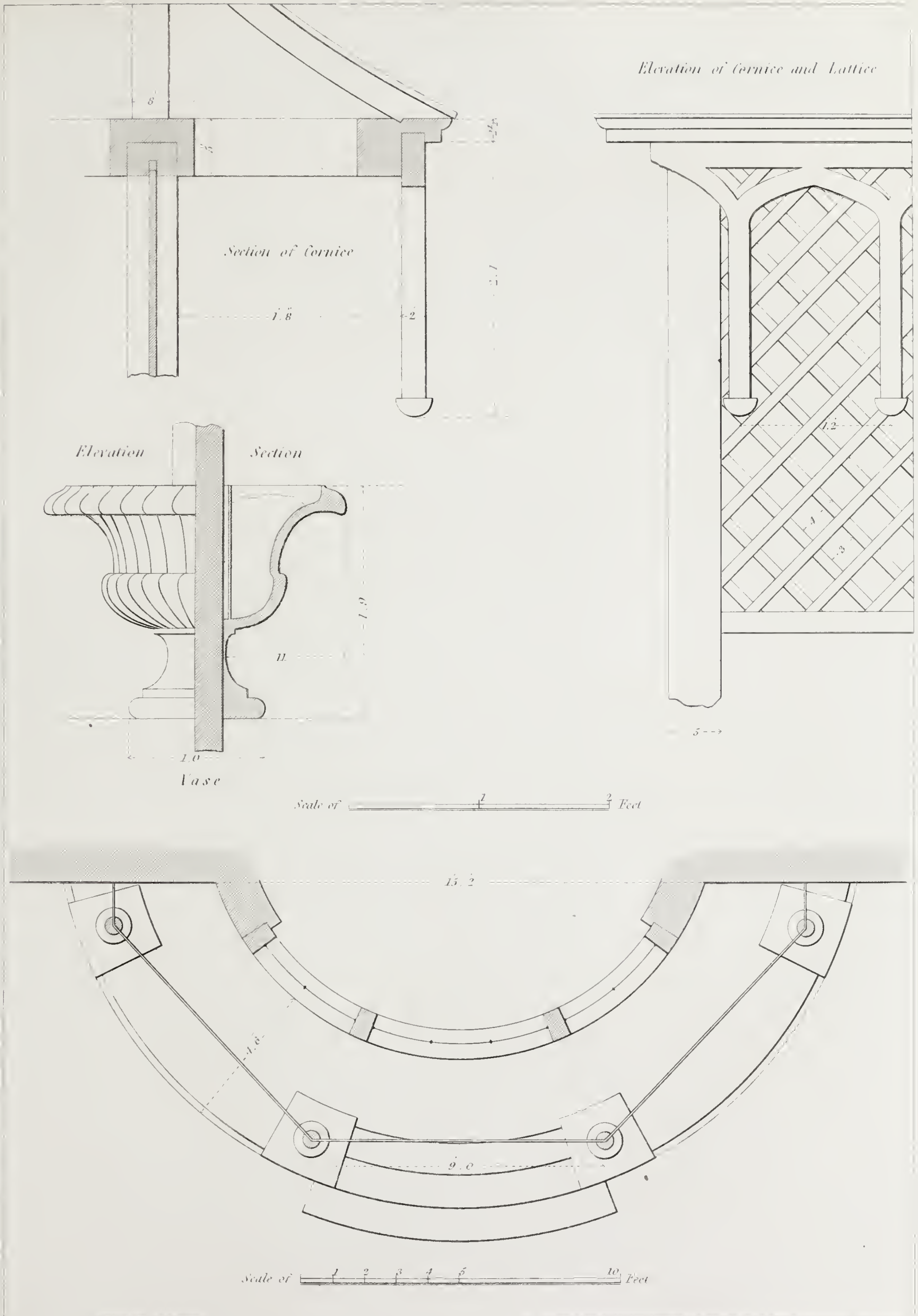


F. Arundale del.

J.W. Lowry sc.

DESIGN FOR VERANDAH.

London, John Weale, 59, High Holborn, 1847.



E. Arundale del.

J. W. Lowry fc.

PLAN AND DETAILS OF VERANDAH.

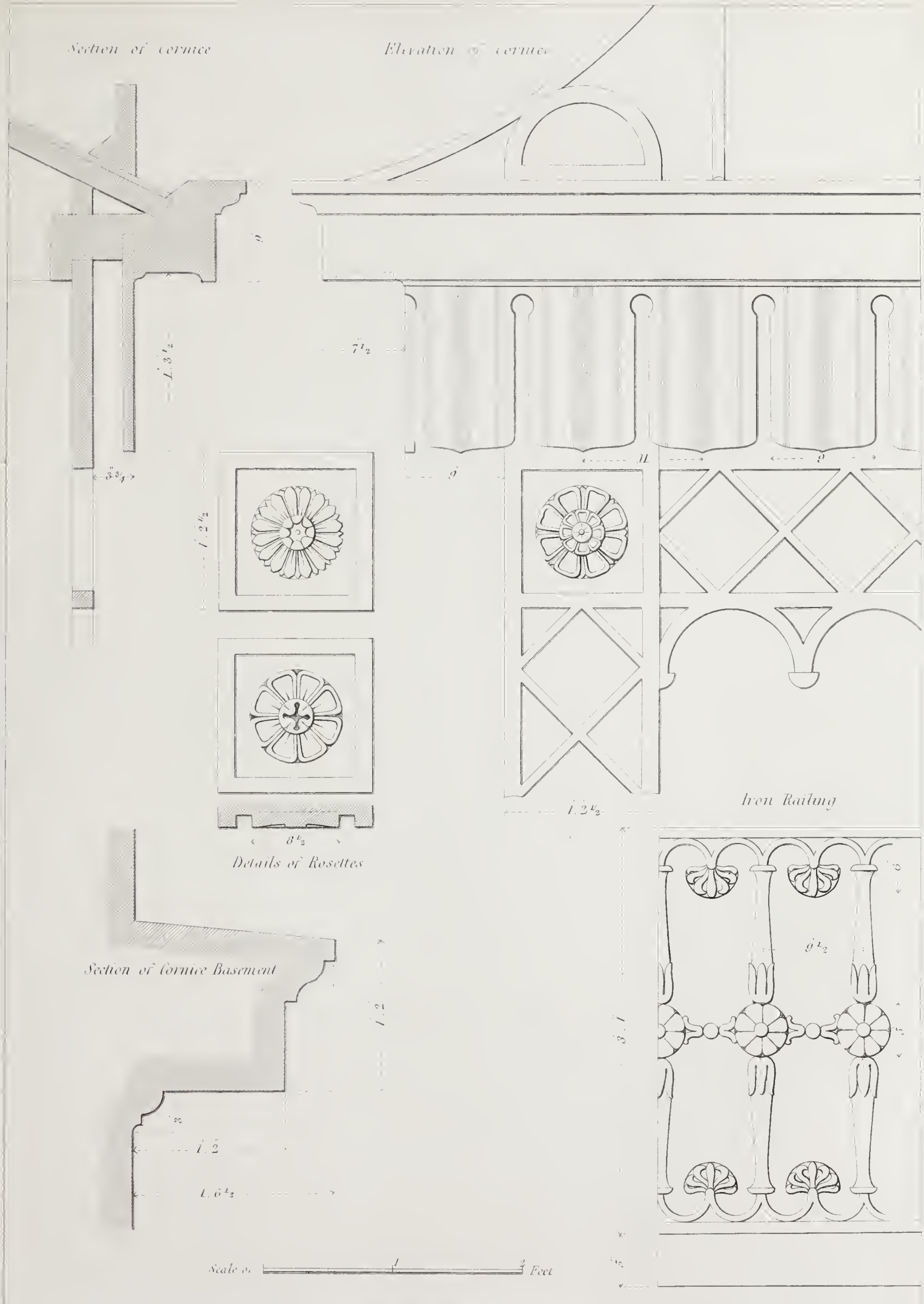
London John Weale 59 High Holborn 184

F. Arundale del.

J. W. Lowry fc.

DESIGN FOR A VERANDAH

London, John Weale 59 High Holborn 1847

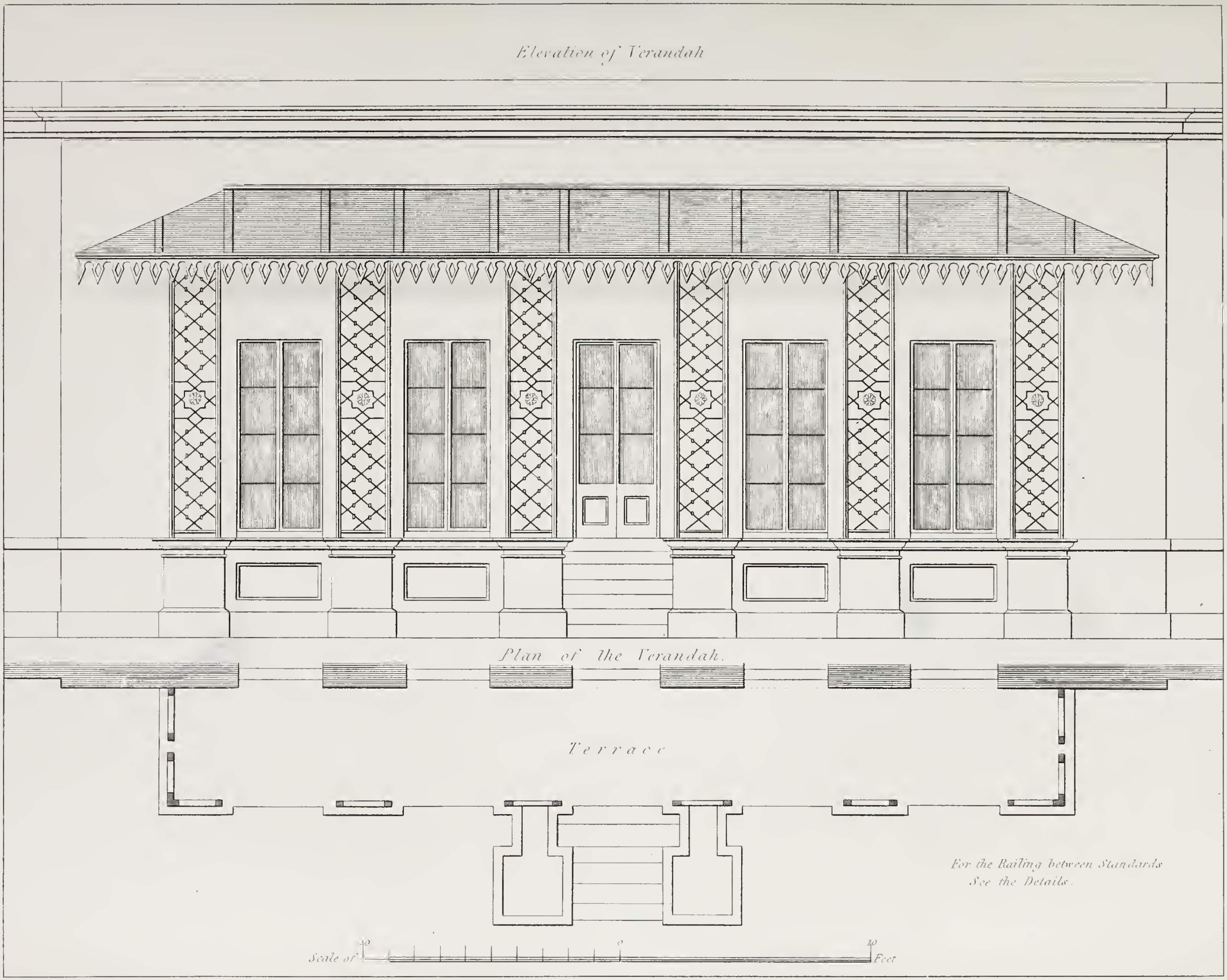


E. Arundale del.

J. W. Lowry fc.

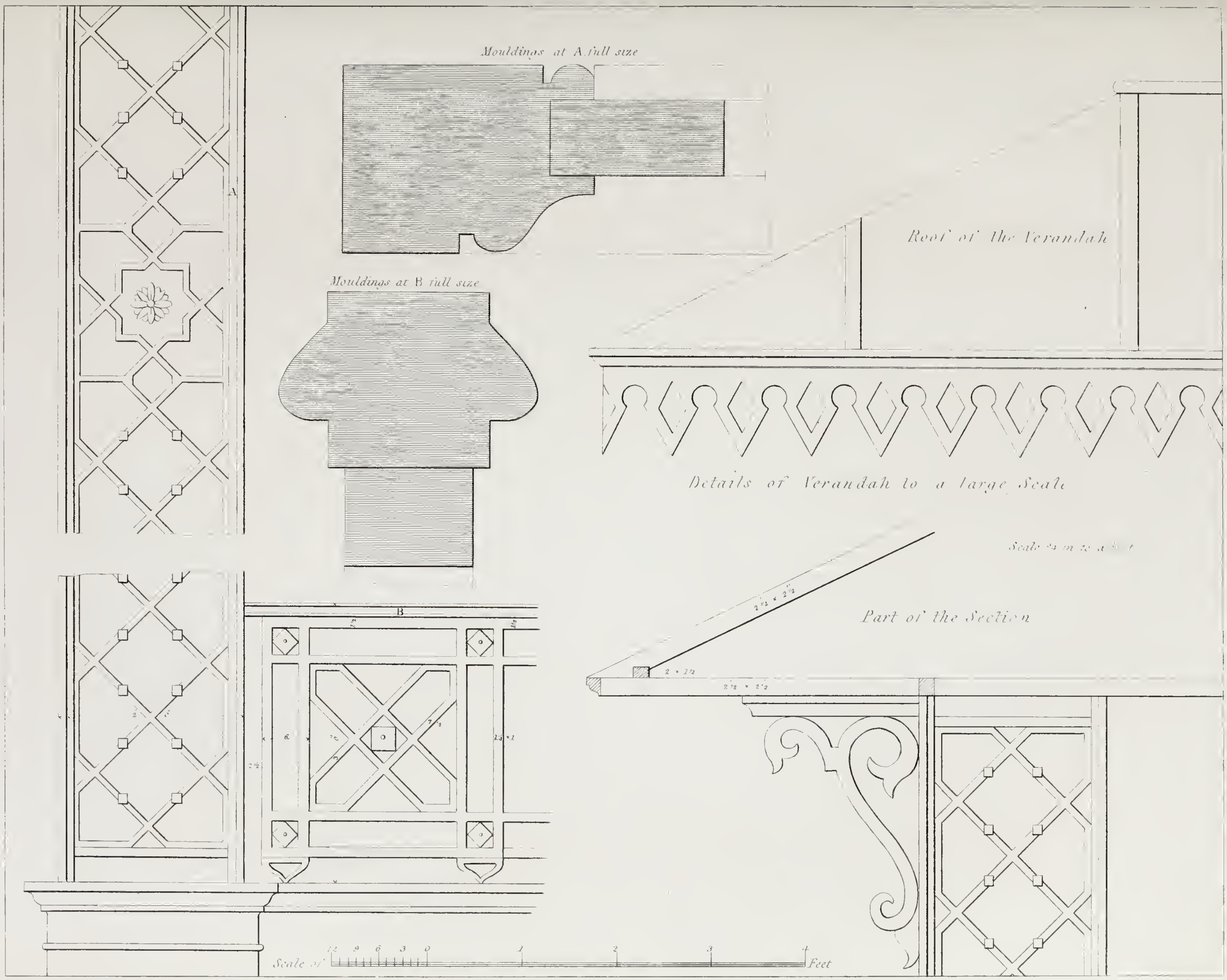
DETAILS FOR VERANDAH

London, John Weale, 59, High Holborn, 1847.



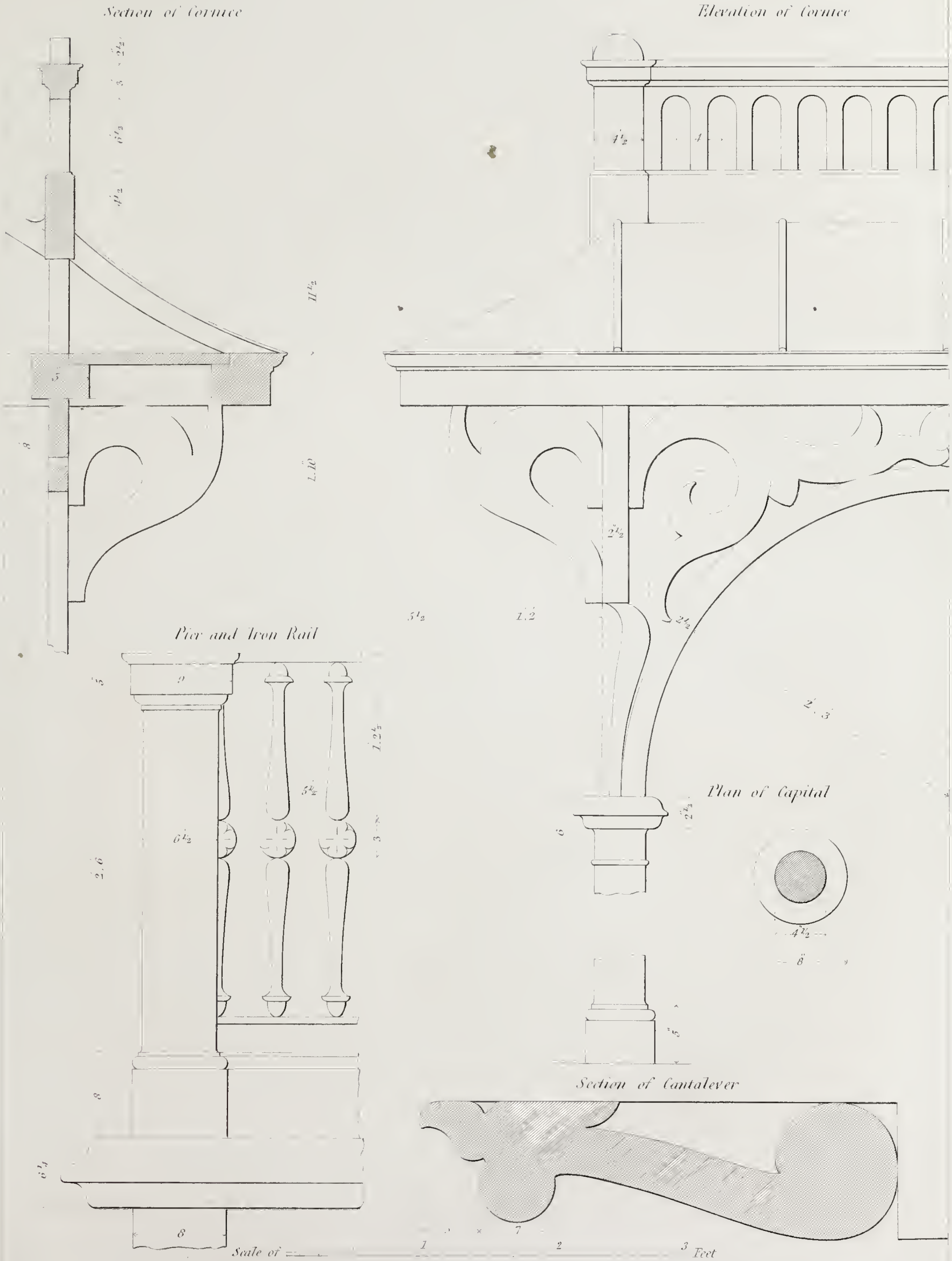
Drawn by E. W. Tendall

John Weale, June 1, 1847.



Drawn by E. W. Bindall

John Weale June 1, 1847



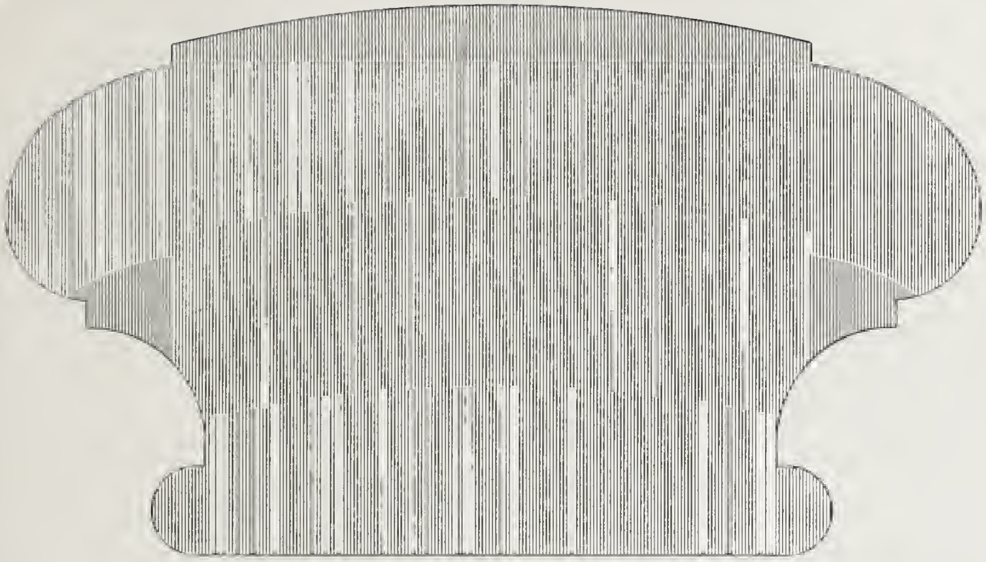
E. Arundale del.

J. W. Lowry fc.

DETAILS FOR VERANDAH

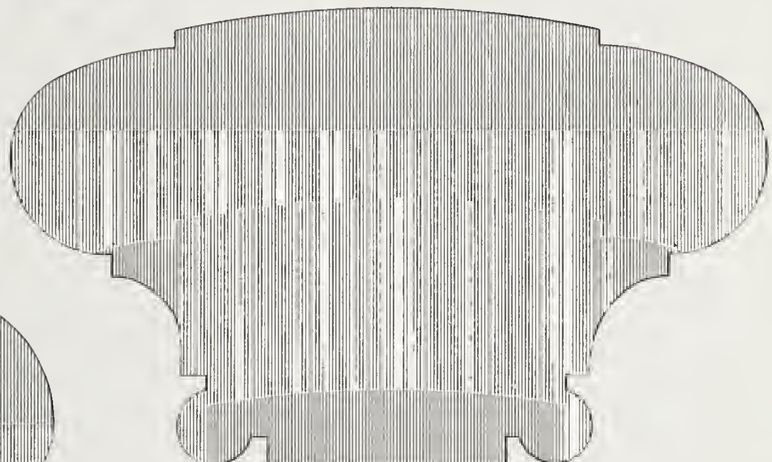
London John Weale, 59 High Holborn 1847

Hand Rails

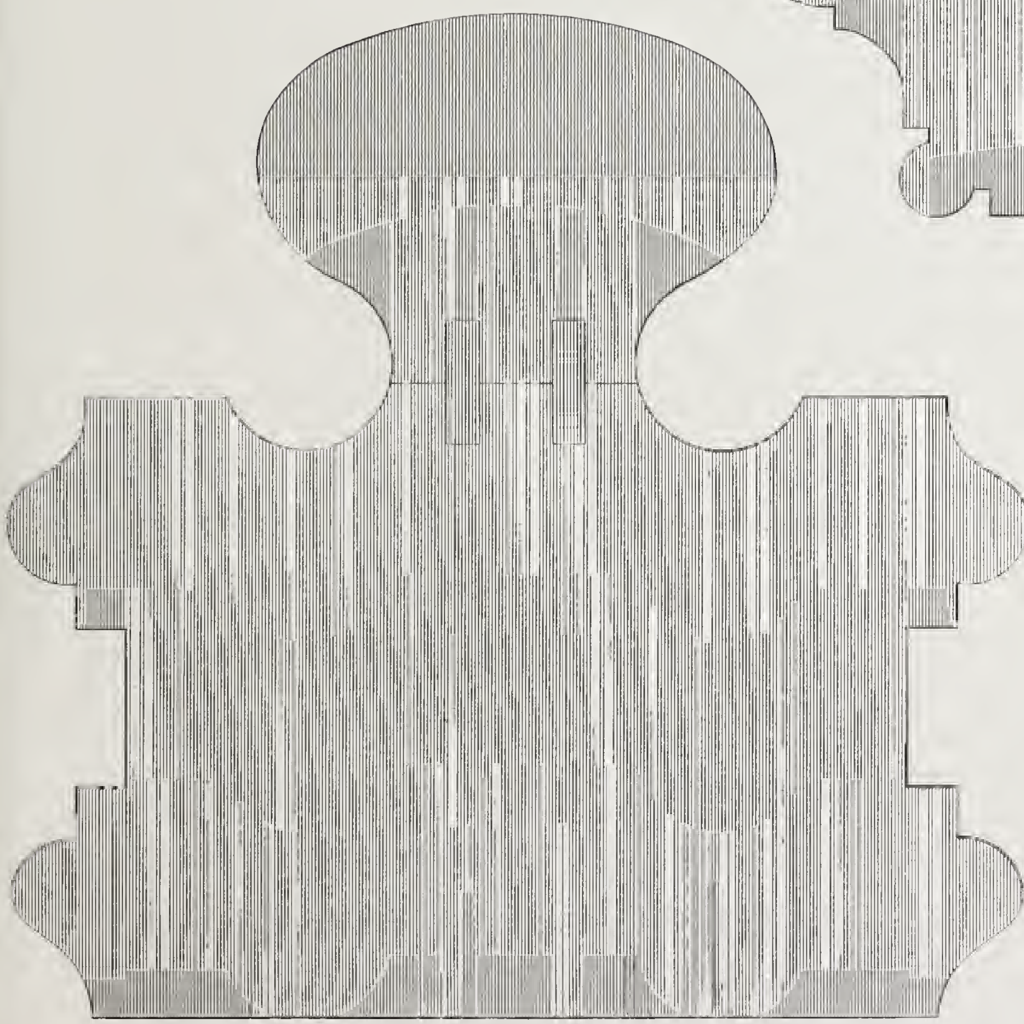


Marquess of Hertford's. Piccadilly.

Sir R. Peel's House Privy Gardens



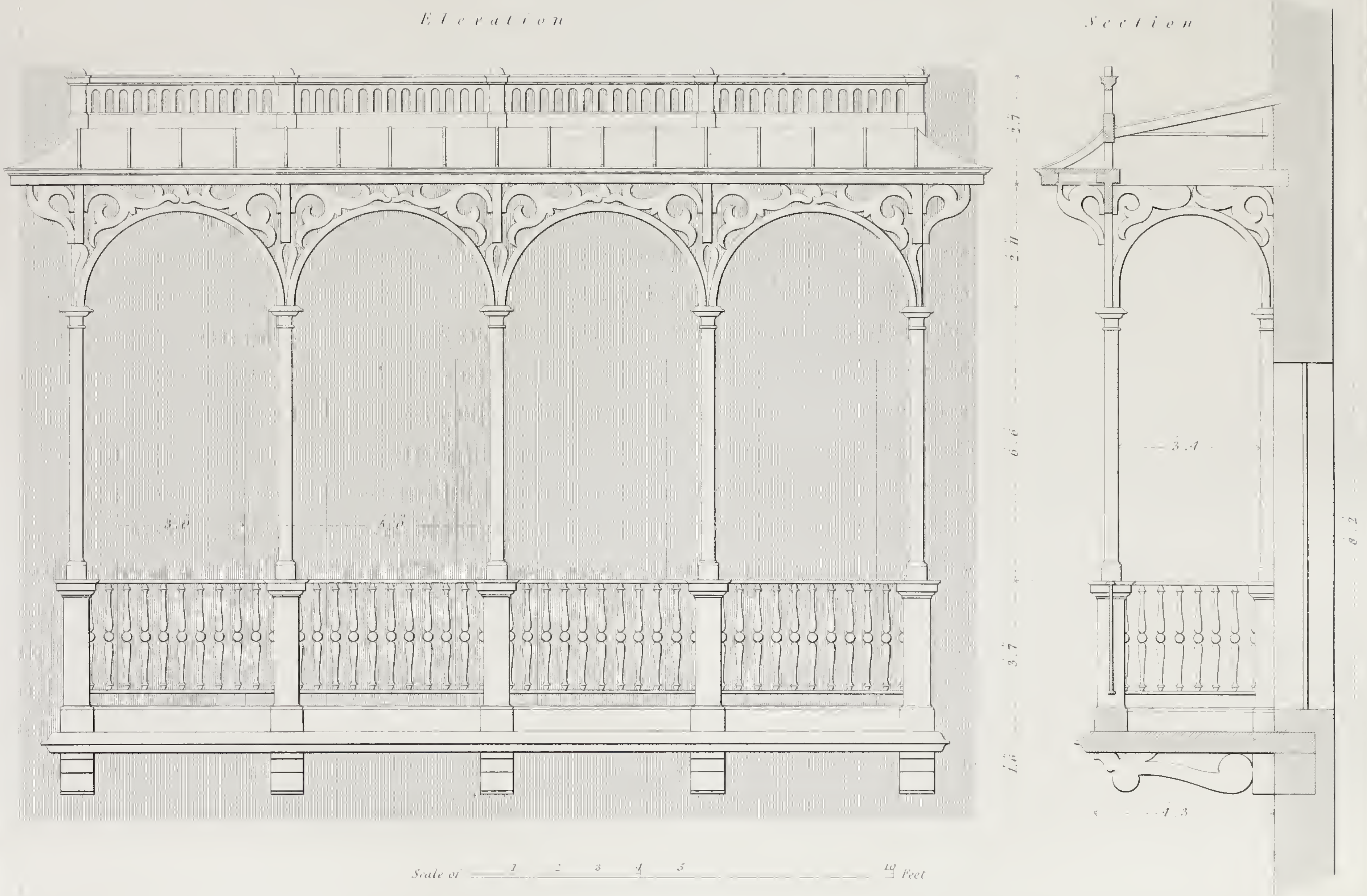
Full Size



Moreby Hall Yorkshire

John Weale, June 1. 1847

Practical, B



E. Arundale del

J. W. Lowry f.

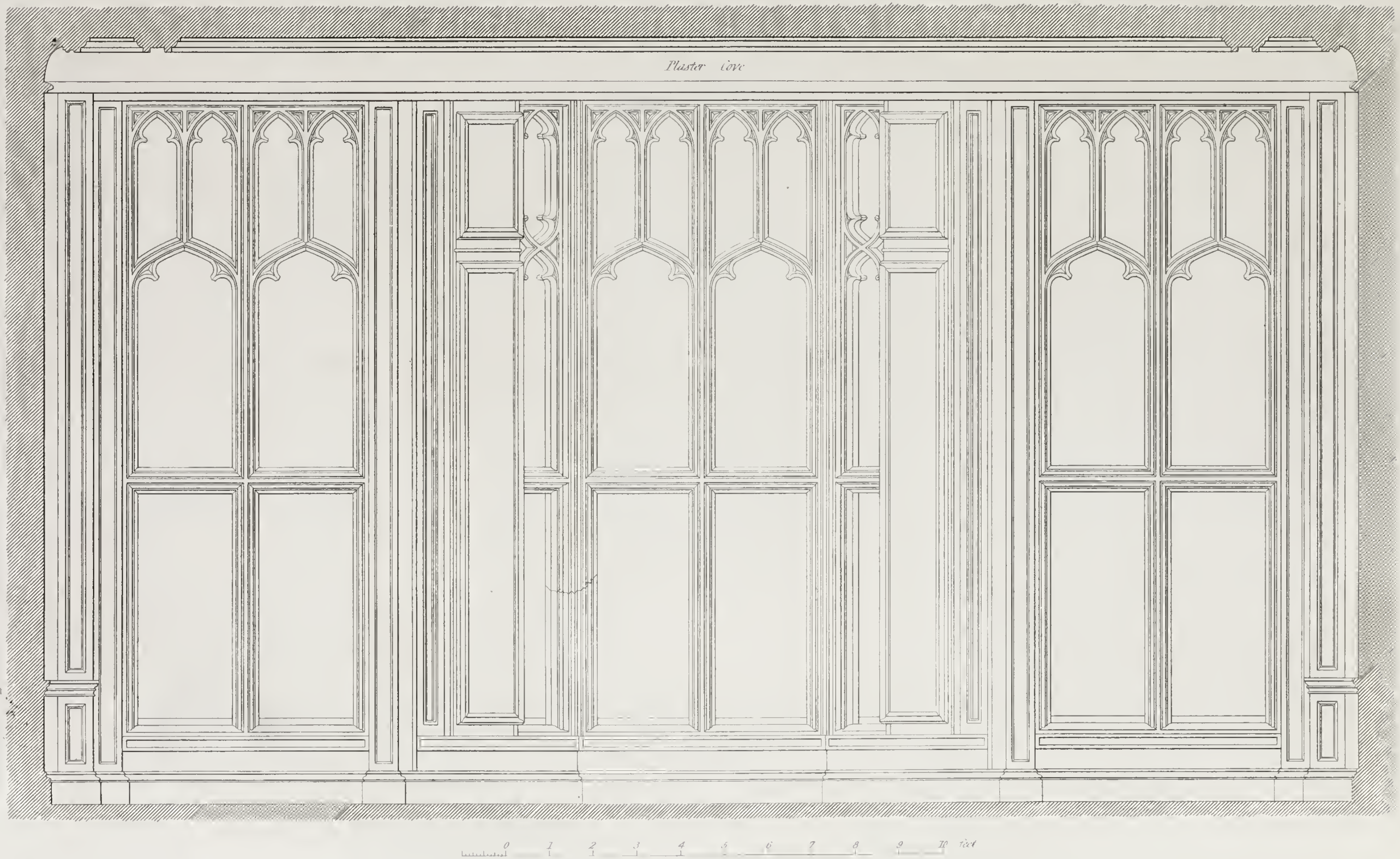
DESIGN FOR A VERANDAH

London, John Weale, 59 High Holborn 1847

WINDSOR CASTLE

The Window side of one of the Private Apartments in the East Front

See plan of one half, to a larger scale.



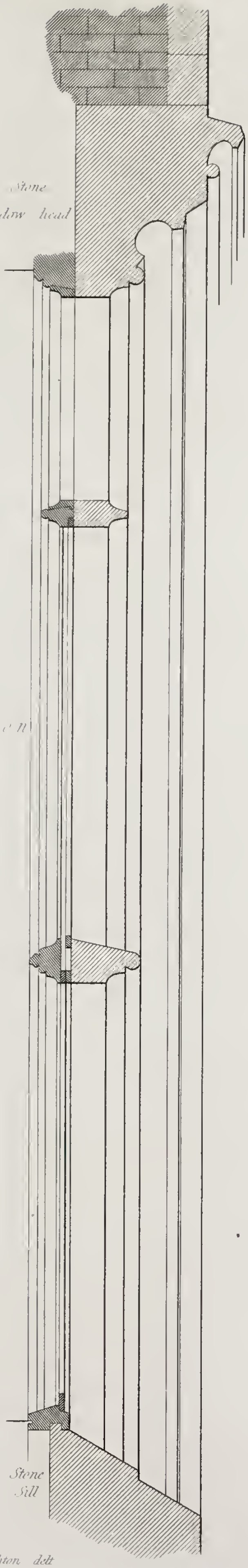
The moldings & panels are carved

H. Ashton. del^t

John Weale 1847

WINDSOR CASTLE

Wainscot Window Frame and Sashes for the Private Apartments in the East Front



H Ashton delt

John Weale 1847

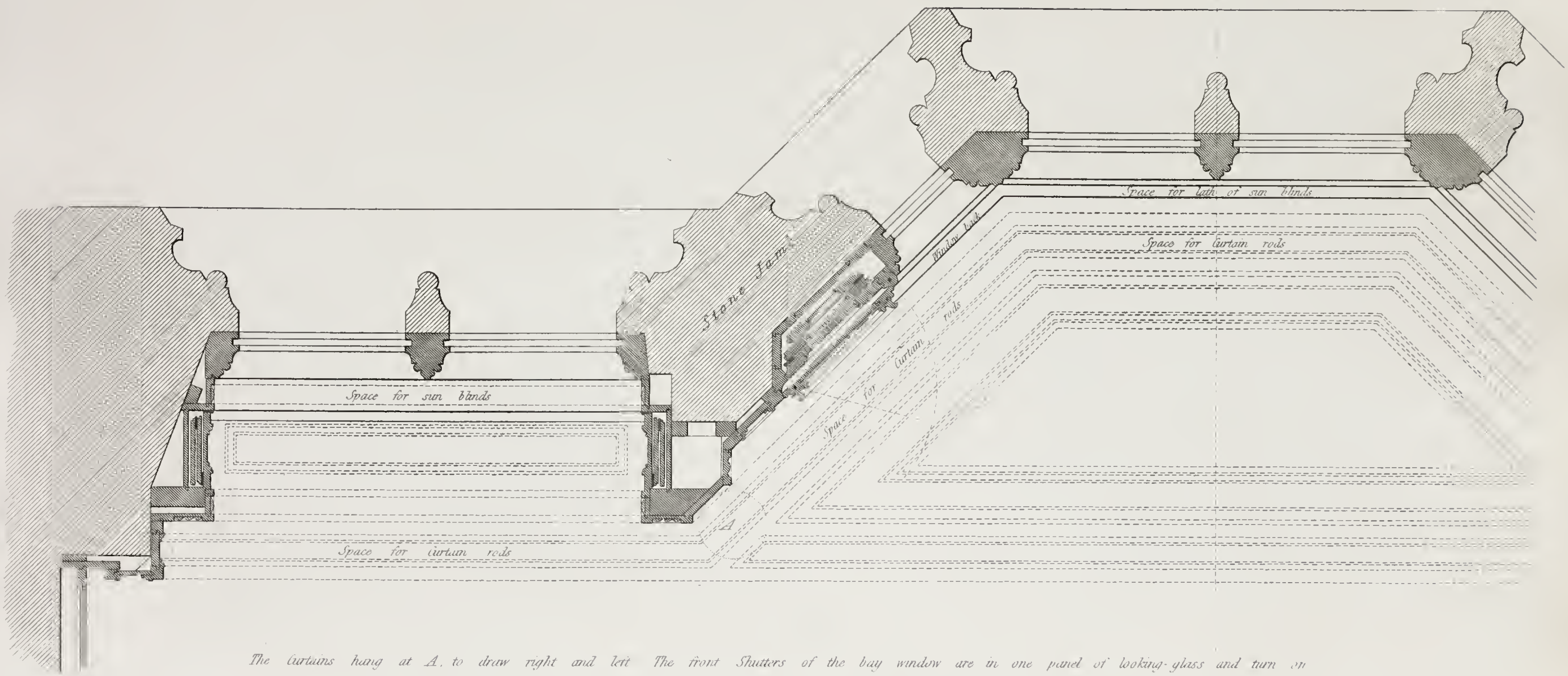
Gladwin sculp

WINDSOR CASTLE

Plan of one half of the Window side of one of the Private Apartments in the East Front

shewing the Shutters, boxings, and linings, as directed by the late Sir J Wyatville;

and executed by Mess.rs Armstrong & Smith, Pimlico



The Curtains hang at A, to draw right and left. The front Shutters of the bay window are in one panel of looking-glass and turn on centres, as do also the back flaps; the dotted lines shew the soffit

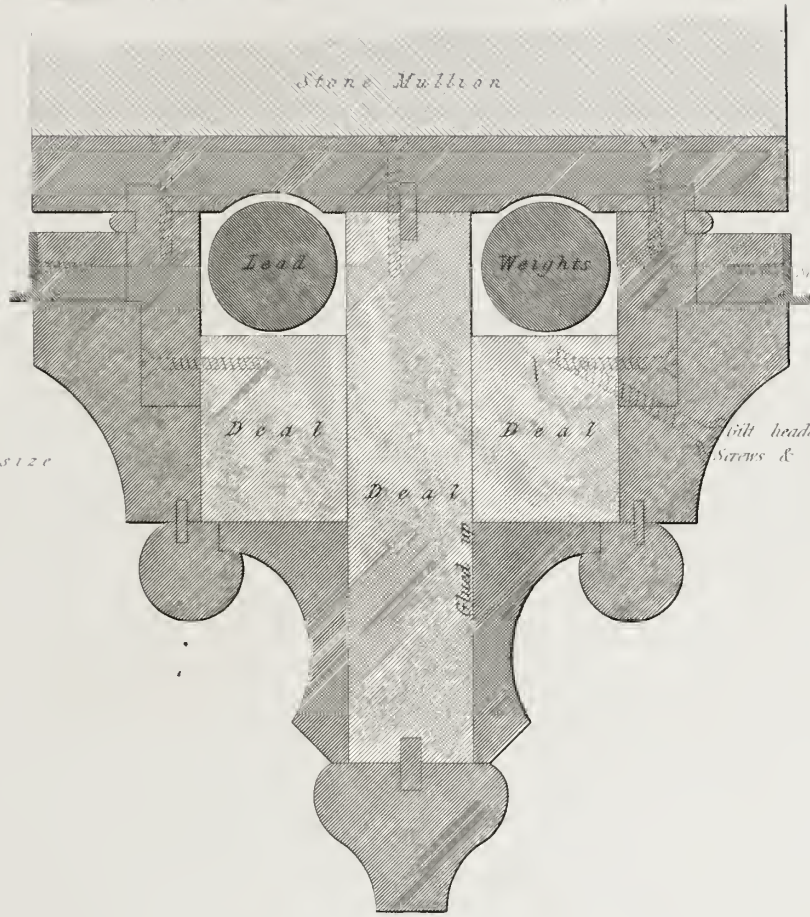
Half inch scale

H Ashton delt

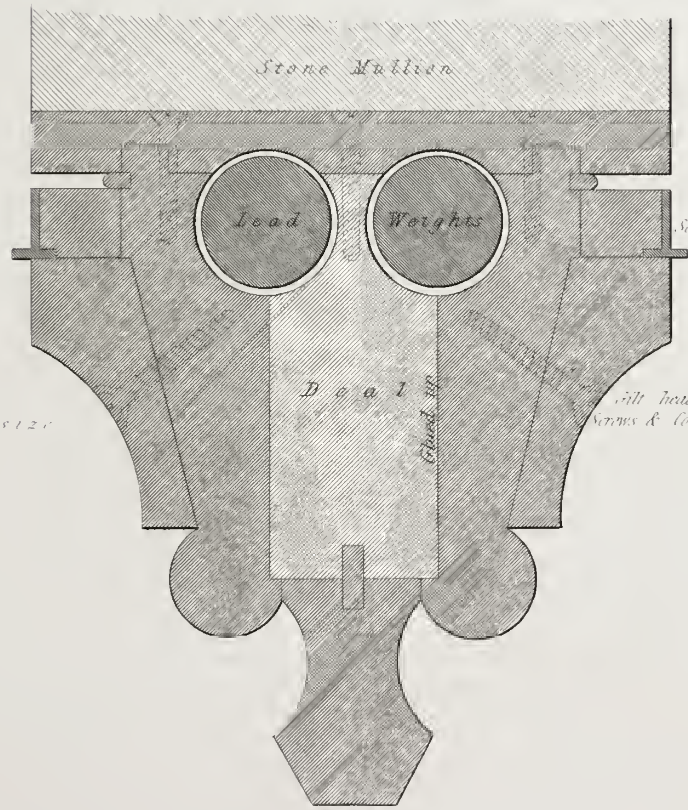
G Gladwin sculp

John Weale, 1847

Mullion of ... Window ... and Sashes in the Brunswick ... Tower



Mullion of Wainscot Window Frames and Sashes in the Private Apartments.



WINDSOR CASTLE

Plan of one half of the Bay Window in the State Drawing Room

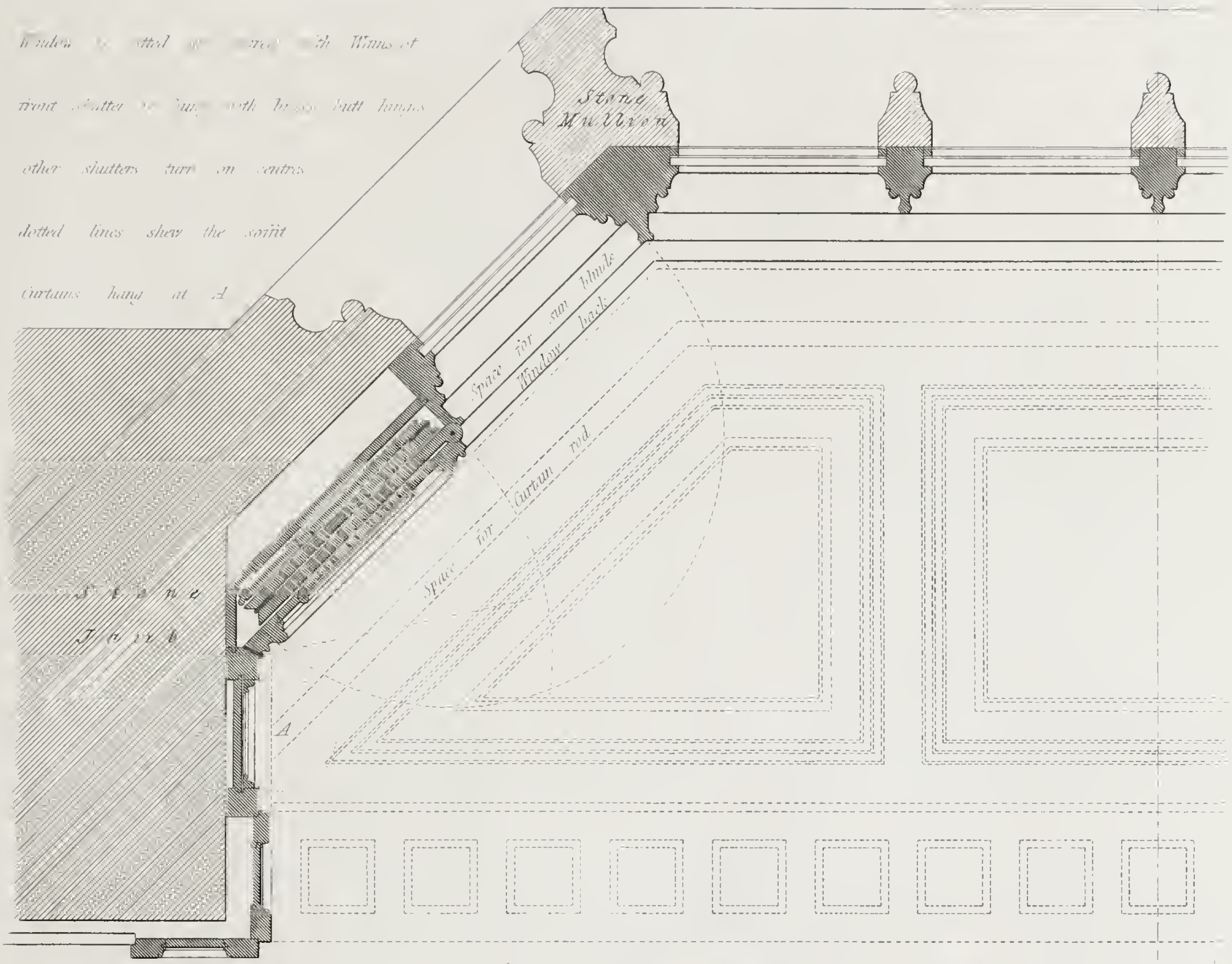
The Window to be fitted up with Wainscot

The front shutter to hang with brass butt hinges

The other shutters turn on centres

The dotted lines shew the soffit

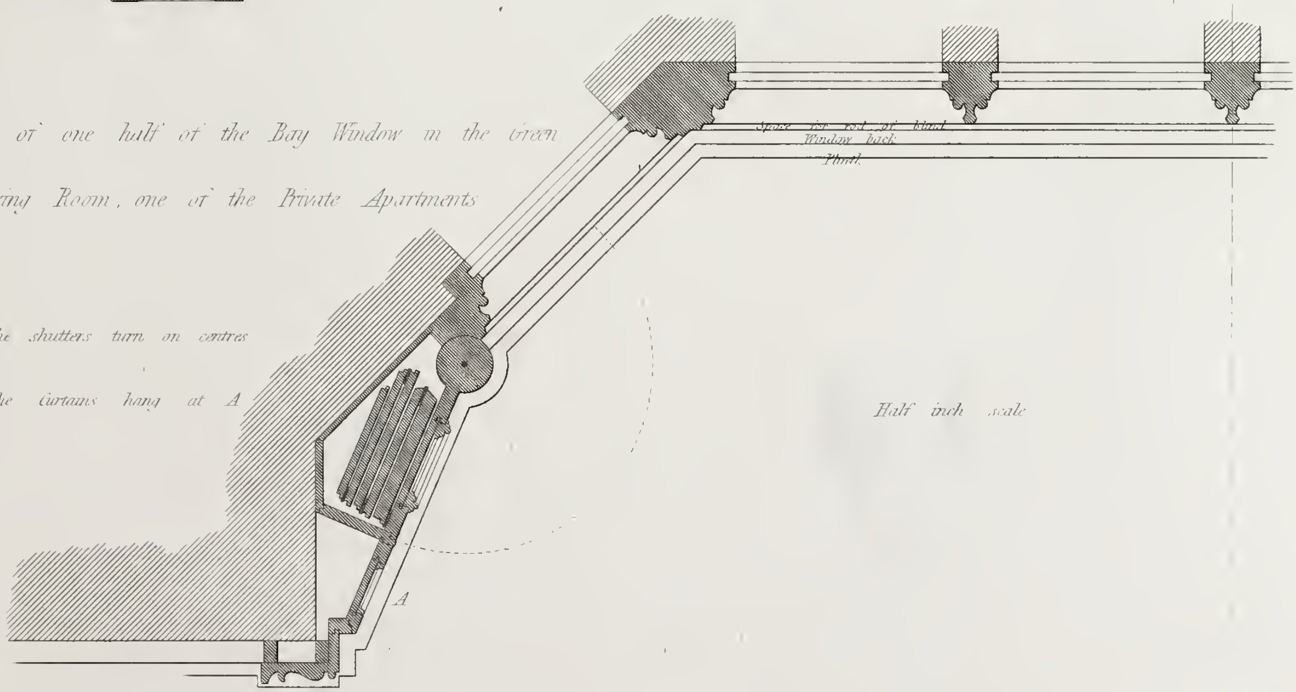
The Curtains hang at A



Plan of one half of the Bay Window in the Green Drawing Room, one of the Private Apartments

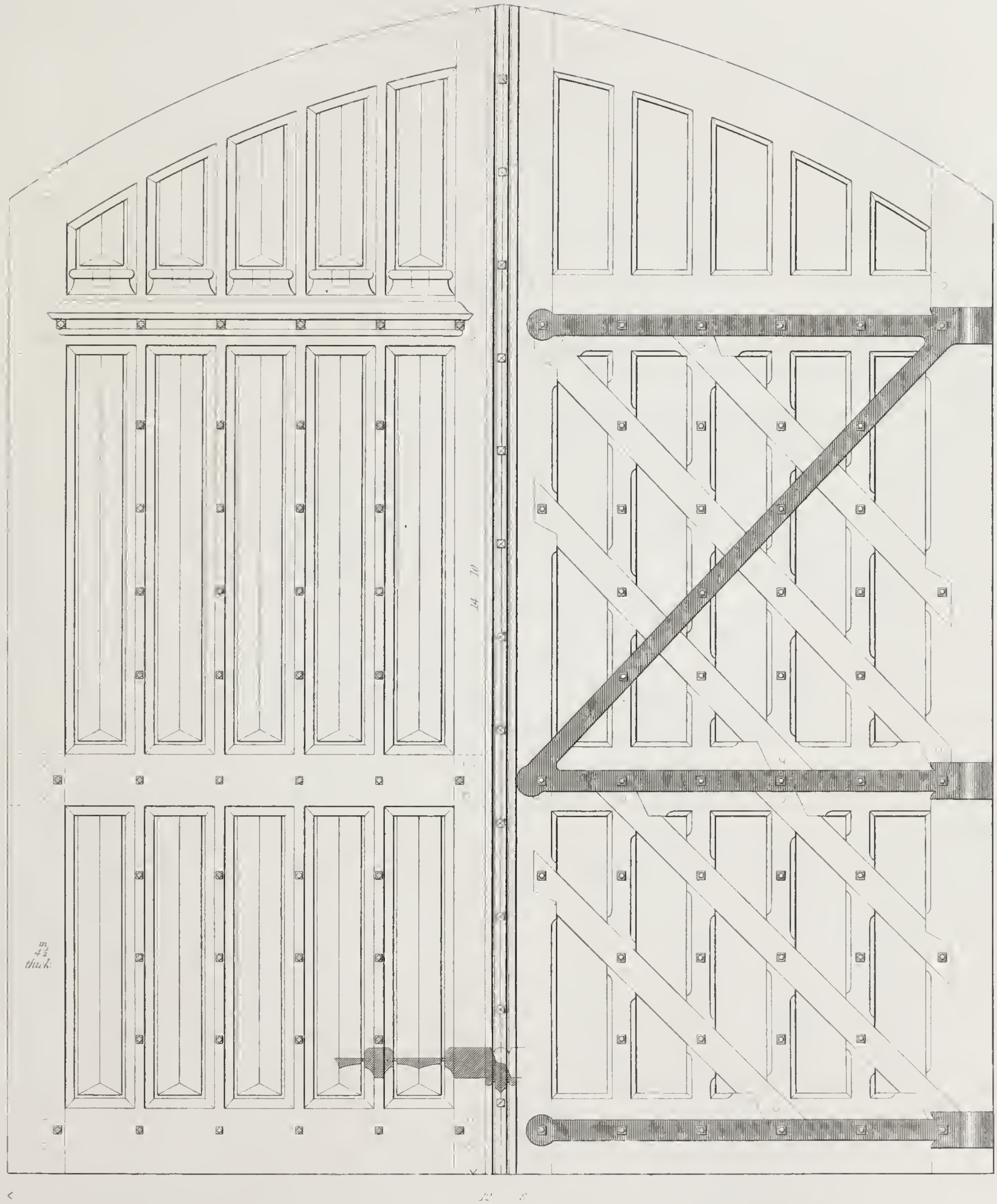
The shutters turn on centres

The Curtains hang at A



Half inch scale

WINDSOR CASTLE



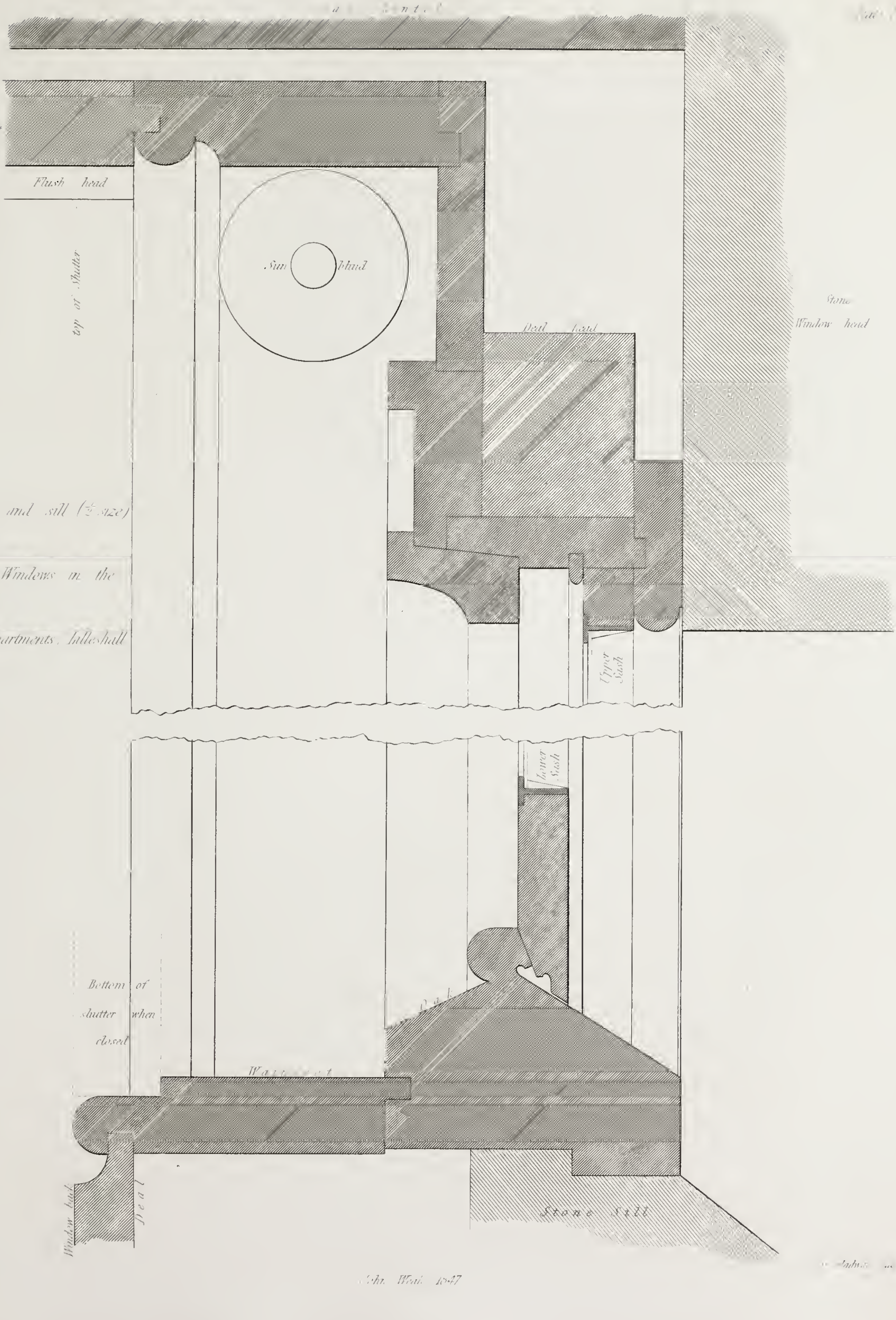
Front of the Gate — *Back of the Gate*

These Gates are of English Oak 4½ ins thick and were made by Mess.rs Cressell & Co.

half inch scale

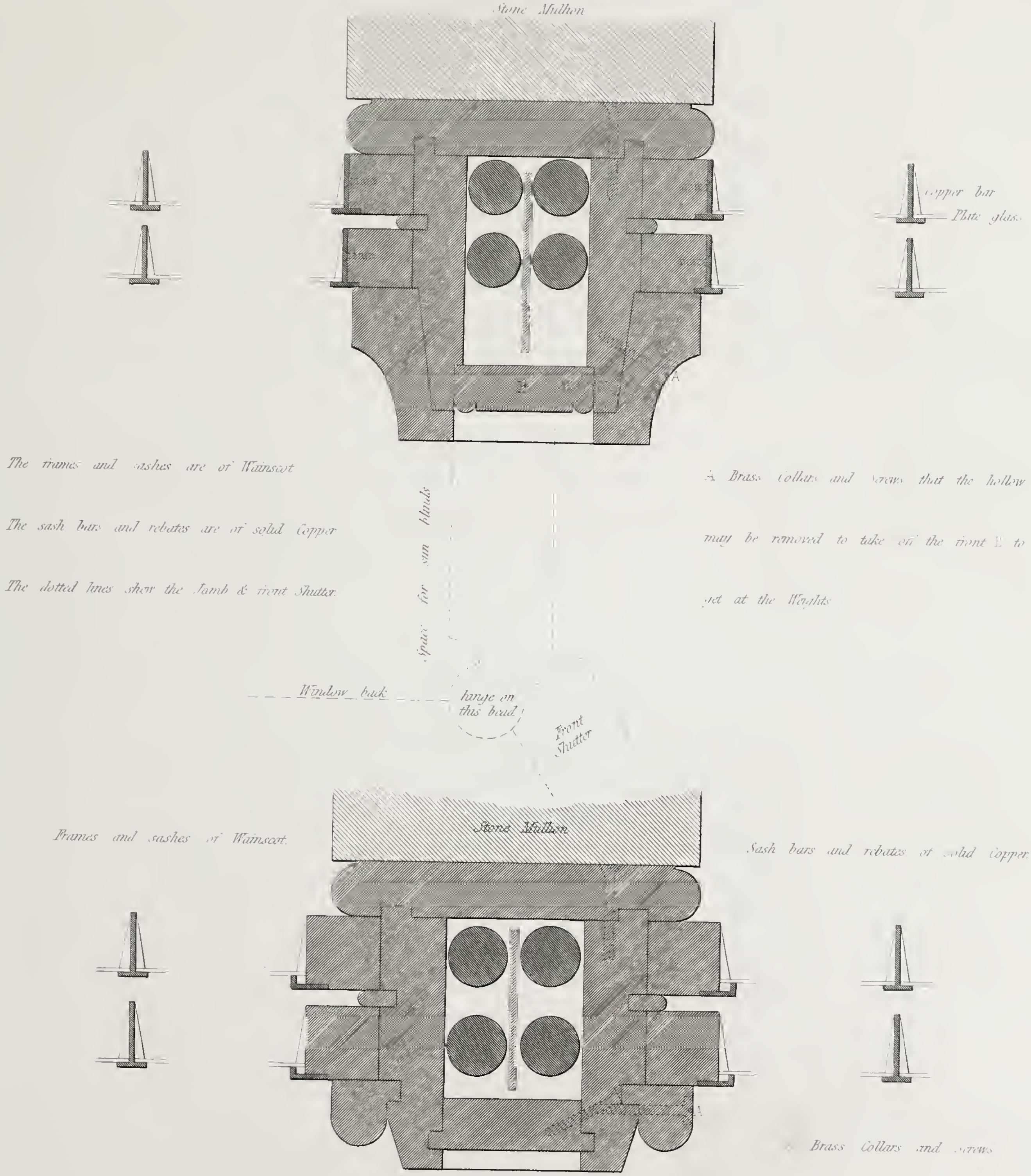
Asmus delt

John Weale 1847



The head and sill (½ size) of the Windows in the Family Apartments, Lilleshall

Mullions & Window Frames in the Family Apartments at the Duke of Sutherland's Mansion, Lilleshall, Shrop



Mullions of Windows on the Chamber story, Lilleshall

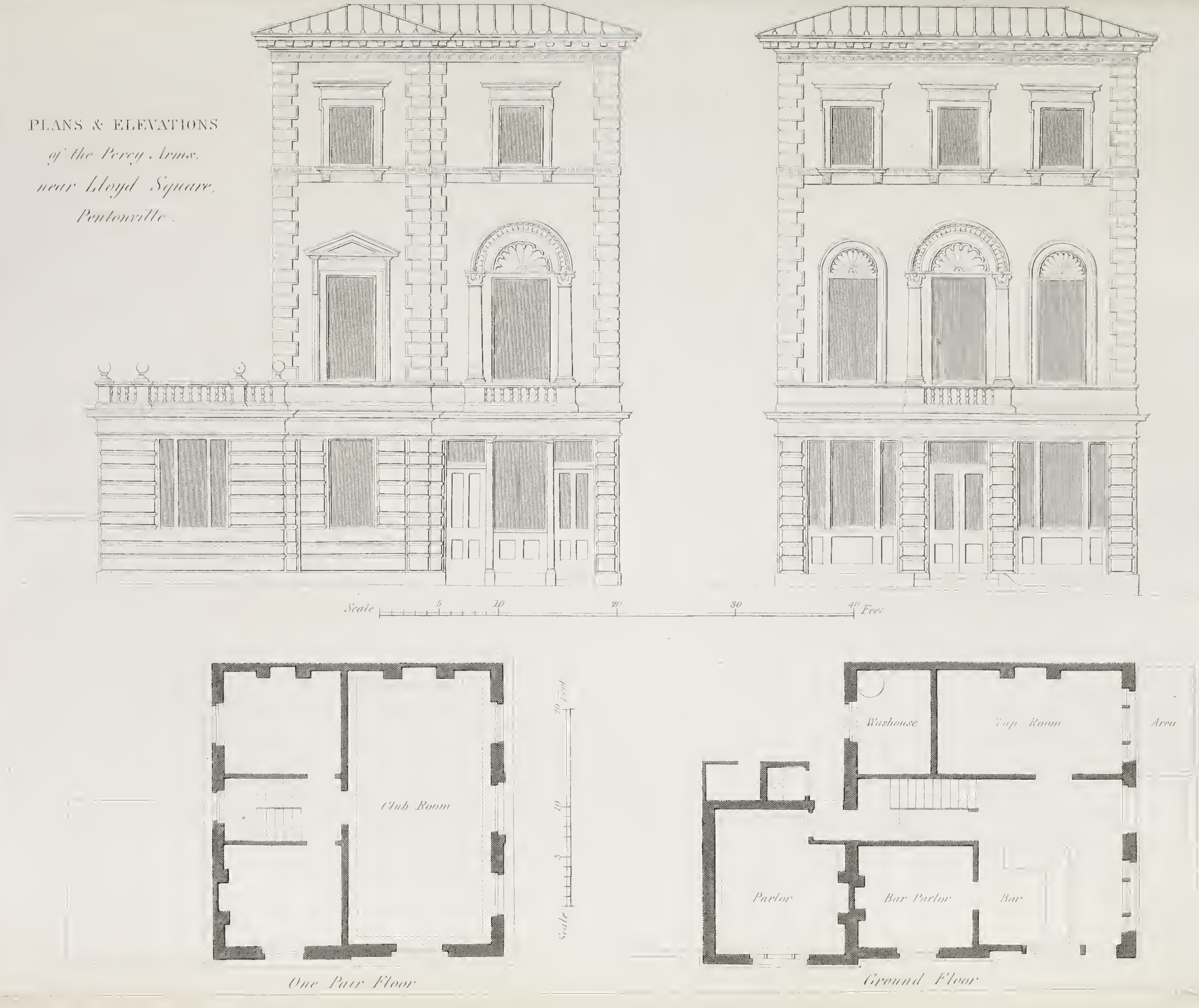
Designed by Sir J. Wyatville, & made by Mess.rs Armstrong & Smith Pimlico

Half size

Ashton del.

John Weale 1847

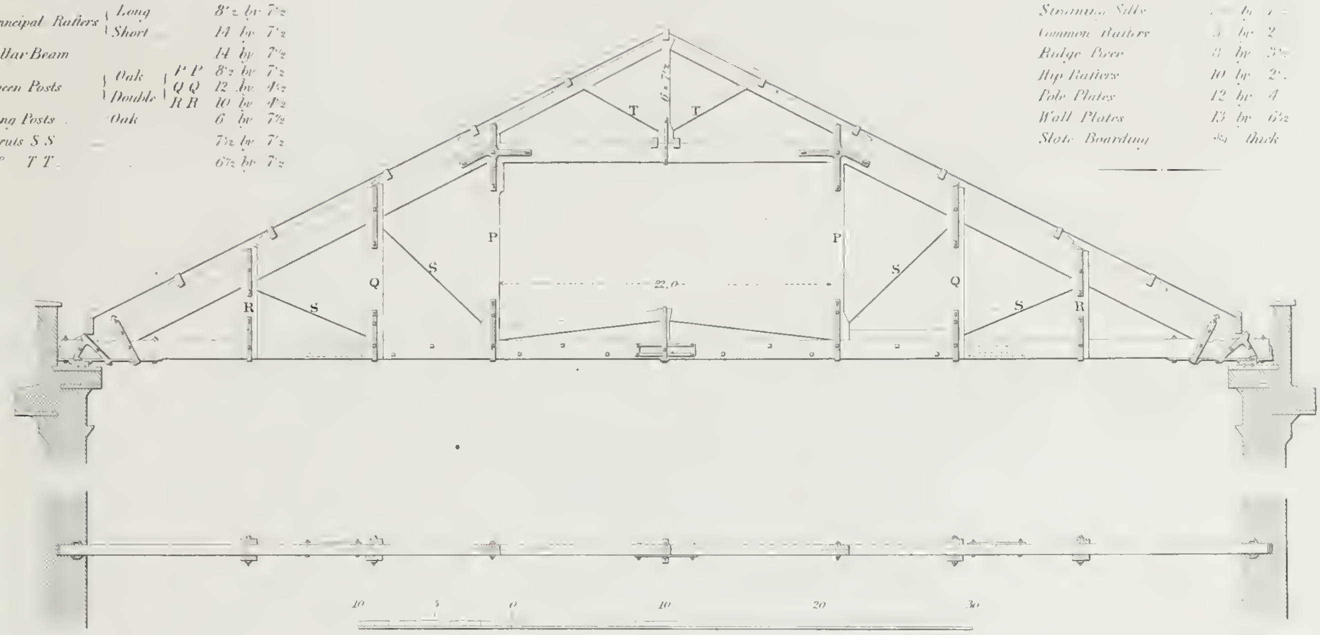
PLANS & ELEVATIONS
of the Percy Arms,
near Lloyd Square,
Pentonville.



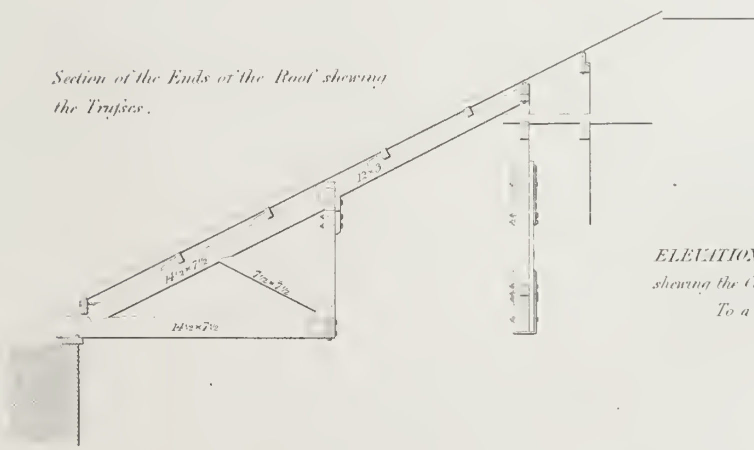
EXETER HALL ROOF.

SCANTLINGS			
Tie Beam			14½ by 7½
Principal Rafters	Long		8½ by 7½
	Short		14 by 7½
Collar Beam			14 by 7½
Queen Posts	Oak	P P	8½ by 7½
	Double	Q Q	12 by 4½
		R R	10 by 4½
King Posts	Oak		6 by 7½
Struts S S			7½ by 7½
D° T T			6½ by 7½

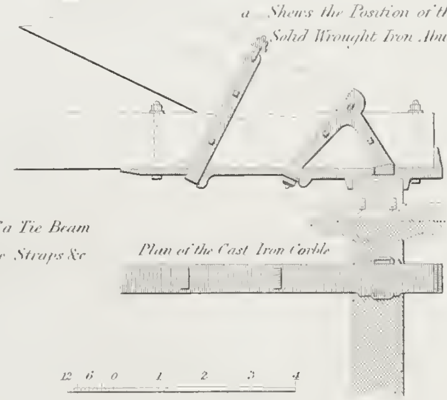
SCANTLINGS	
Straining Sills	[illegible] by [illegible]
Common Rafters	5 by 2
Ridge Piece	8 by 3[illegible]
Hip Rafters	10 by 2[illegible]
Pole Plates	12 by 4
Wall Plates	13 by 6½
Slate Boarding	¾ thick



Section of the Ends of the Roof shewing the Trusses.



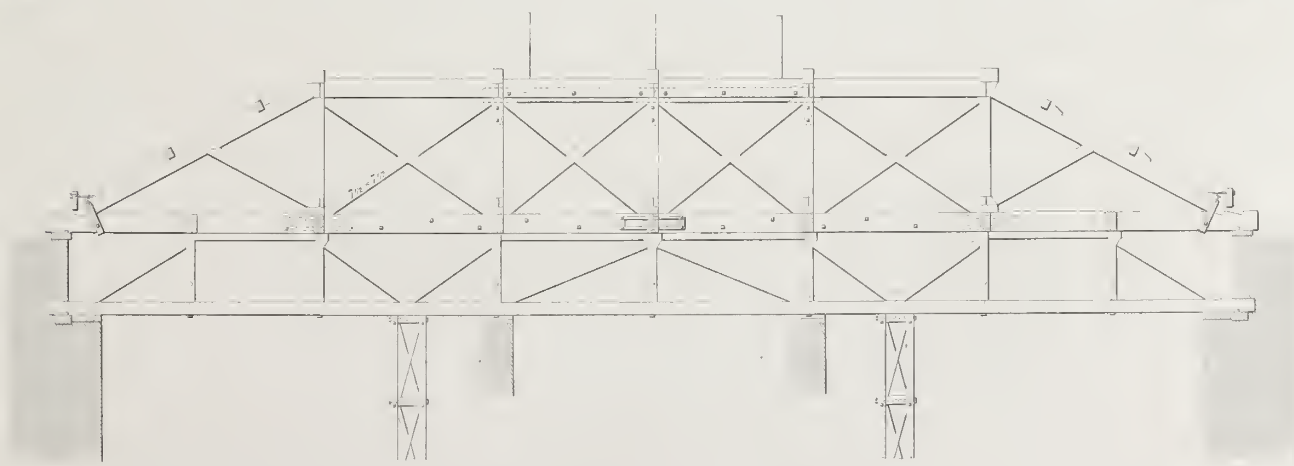
a Shews the Position of the Solid Wrought Iron Abutment



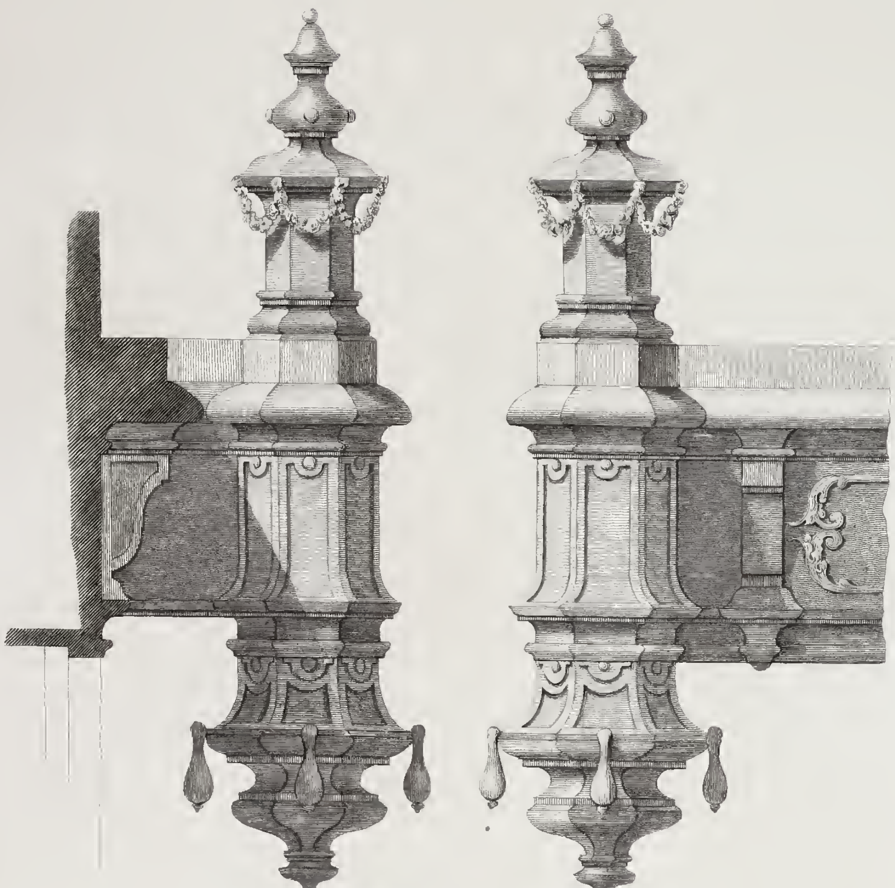
ELEVATION of the End of a Tie Beam shewing the Cast Iron Corble Straps &c To a Larger Scale.

Plan of the Cast Iron Corble

12 6 0 1 2 3 4

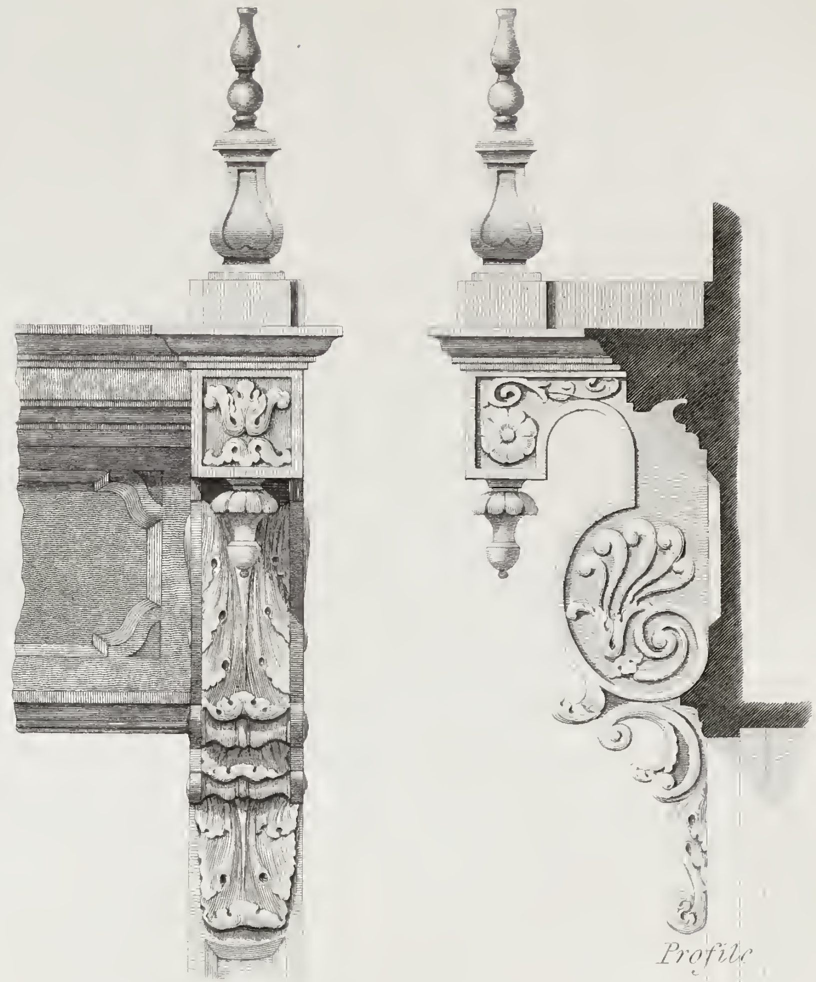


Elizabethan terminations of a Shop Front Entablature.



Profile Front

Consol terminating the Entablature of a Shop Front Pimlico

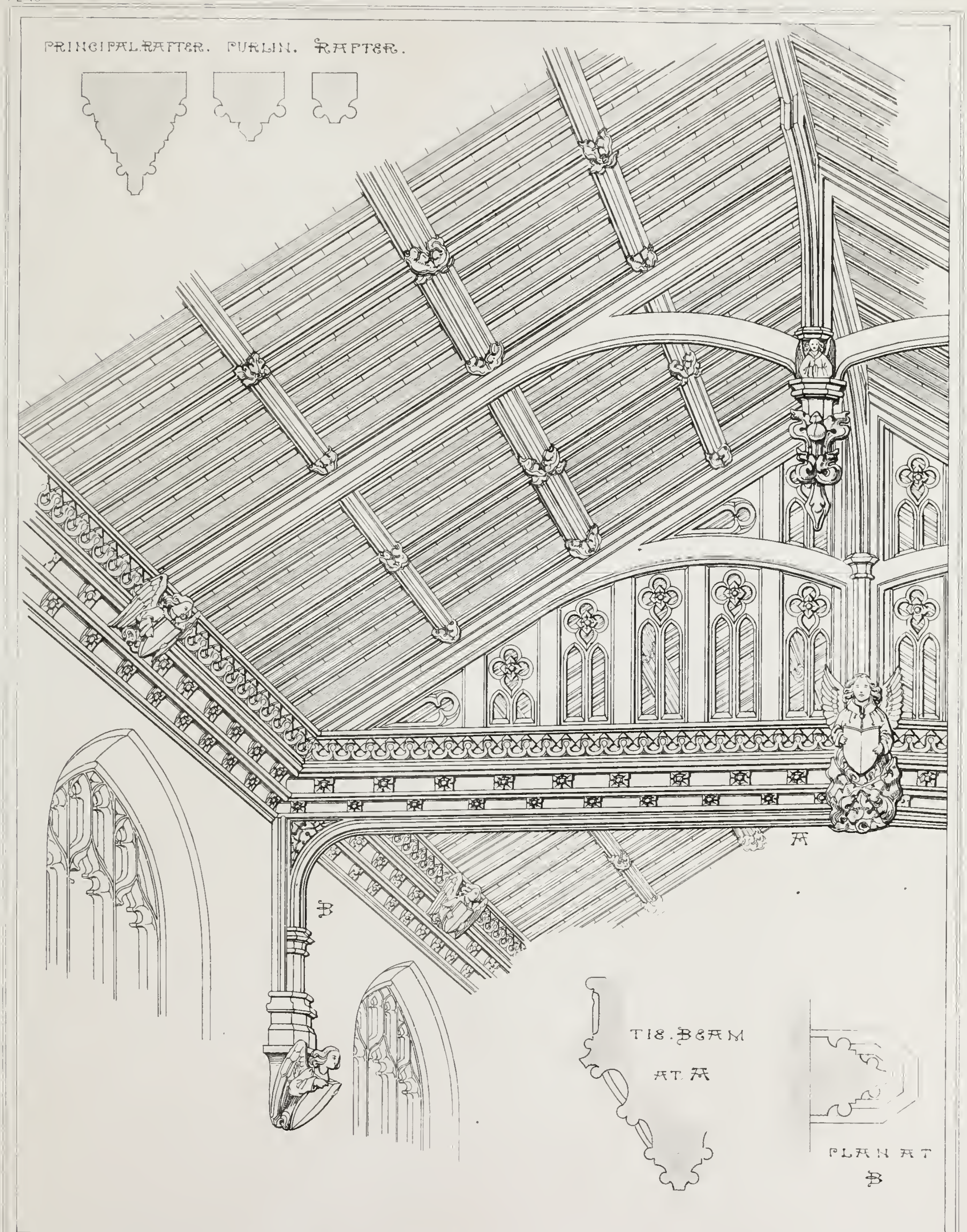


Front Profile

F. Gifford, del.

Hawksworth sc.

John Weale, 1848



BURY DEL & SC.

THE ROOF OF THE NAVE . S . MARY . WESTONZOYLAND . SOMERSETSHIRE .